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NOVEMBER 1958

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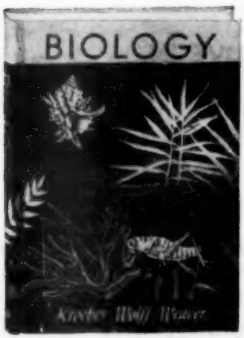

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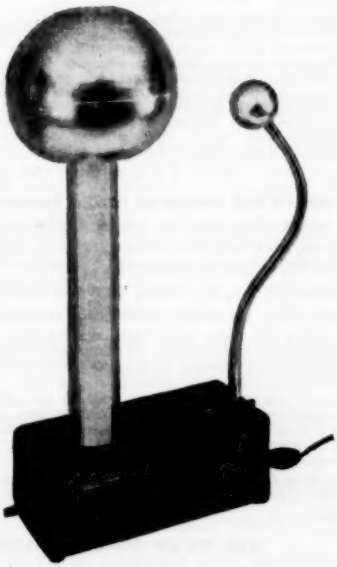

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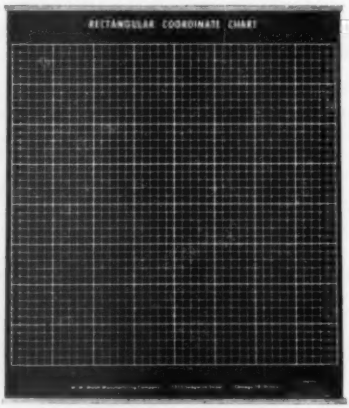

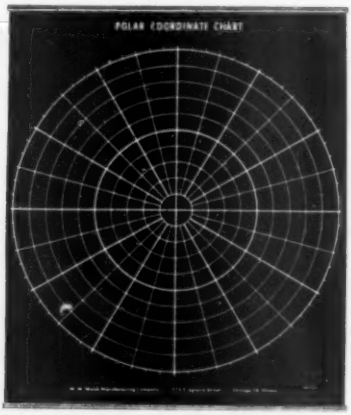

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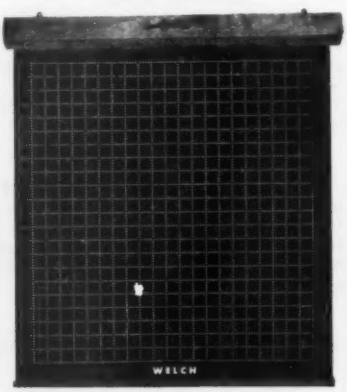

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VOL. LVIII NOVEMBER, 1958 WHOLE NO. 514

Models Depicting Some Groups of Movements*

Lindsay L. Hess

Bozeman Senior H. S., Bozeman, Montana

INTRODUCTION

During my junior year in high school, 1956–1957, I prepared an exhibit illustrating Group Theory for the District Science Fair. My exhibit was developed in two parts: one is a set of mathematical multiplication tables, and the second is several balsa wood models representing some groups. For each group I made two models; one represents the figure with all its axes and the second is a working model upon which all of these multiplications or operations may be performed.

The first successful application of Group Theory was made by Evariste Galois, a remarkable young mathematician who died at the age of twenty years because of political activity in early nineteenth-century France. Niels Abel, a brilliant Norwegian mathematician, also contributed to Group Theory. Like Galois, Abel died young. Of these young men it has been said that they left ideas that "will keep generations of mathematicians busy for hundreds of years."[1]

Below, I list some groups, and, later, I explain how I made the models representing these groups.

MODELS FOR SOME GROUPS OF MOVEMENTS

The arithmetic operation of addition with integers and of multi-

* EDITOR'S NOTE: This article was prepared by a high-school student and is part of a project prepared for the District and National Science Fairs. Mr. Hess received a Fourth Place Rating on his project at the National Science Fair in Flint, Michigan in May 1958.

[1] Bell, E. T., *Men of Mathematics*, Simon and Schuster, 1937, p. 377.

plication with rational numbers (zero omitted) and the telling of time are examples of groups.[2]

A group is composed of elements, an equals relation, and one operation (which we shall call abstract multiplication and denote by the symbol $\times$) subject to the following four postulates:

1. The system is closed under the operation $\times$, which is well defined.
2. The operation is associative; that is,

$$(a \times b) \times c = a \times (b \times c)$$

3. There exists an identity element i such that

$$a \times i = i \times a = a$$

4. Every element a has an inverse a^{-1} such that

$$a^{-1}a = i$$

If a group also satisfies Postulate 5, it is called a commutative or abelian group.

5. The operation is commutative; that is, $a \times b = b \times a$.[3]

Let us define the rotations of a circle with six elements. These elements are as follows

R: a rotation of 60° (That would move A into C, C into E, E into B, etc. See Fig. 1.

R': a rotation of 120° (That would move A into E, etc.)

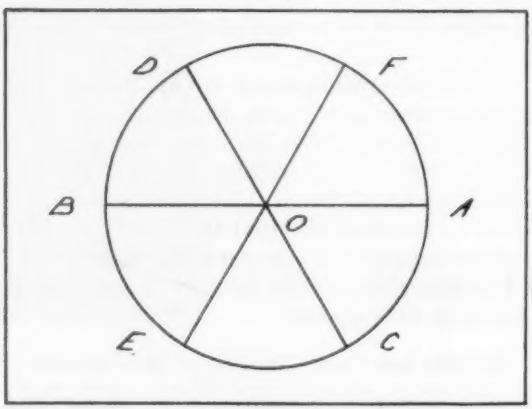

FIG. 1

[2] James, Glenn, *Mathematics Dictionary*, The Digest Press, Van Nuys, California, 1943, p. 117.
[3] Mathewson, Louis Clark, *Elementary Finite Groups*, Houghton Mifflin Company, 1930, p. 2.

R'': a rotation of 180° (That would move A into B, etc.)
R''': a rotation of 240° (That would move A into D, etc.)
R'''': a rotation of 300° (That would move A into F, etc.)
I: no rotation, or a rotation of 360°.

This group of rotations of a circle is an abelian group of order six. (It contains six elements.)[4]

The group of movements of a square is a nonabelian group of order eight. In the square, pass diagonal D through corners 1 and 3; and diagonal D' through corners 2 and 4. See Fig. 2. Now pass a vertical axis V through 0; and pass a horizontal axis H through 0. The eight

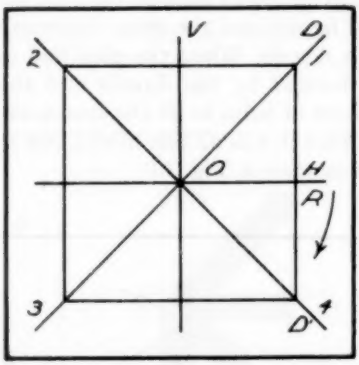

FIG. 2

elements of this group of rotations are defined as follows:

R: a rotation of 90°, clockwise, about 0.
R': a rotation of 180°, clockwise, about 0.
R'': a rotation of 270°, clockwise, about 0.
H: a reflection in the horizontal axis through 0.
V: a reflection in the vertical axis through 0.
I: no rotation or a rotation through 360°.[5]

In performing a multiplication in this group, it is necessary to observe the order in which the multiplication is performed. To multiply $R \times H$, rotate the square 90° about 0; then make a reflection about H and the product is D'. To multiply $H \times R$, first make the reflection about H, then rotate the square 90° about 0 and the product is D. Therefore, $R \times H \neq H \times R$.[6]

The subgroup (a set of elements of the group, which constitute a

[4] *Ibid.*
[5] Birkoff, Garrett, and Saunders MacLane, *A Survey of Modern Algebra*, The Macmillan Company, 1941, p. 1
[6] Allendoerfer, C. B., *Principles of Mathematics*, McGraw-Hill, 1955, p. 79.

group) consisting of the rotations of this group constitutes an abelian group. Movements for an equilateral triangle, a regular tetrahedron, a cube, and a tesseract may be similarly defined.

Construction of Models

In making models of the circle, the square, and the triangle, I constructed two models of each figure. One model of each pair of models was a solid model showing all the axes. These solid models were constructed by making two cutouts of each figure of balsa wood. Then I glued these cutouts on both sides of an arrangement of balsa wood dowels which represented the various axes of the figure. Thus I had axes represented as passing through the plane formed by the two balsa wood figures and the space between them, a space the width of the $\frac{1}{4}$-inch dowels. When the glue had dried, I filled each space (*B*, Fig. 3) formed by the dowels and the representational figures. I shaped pieces of balsa to fill the spaces as closely as possible to convey the idea that it was all one model, not something made of several separate parts. (See *A*, Fig. 3.)

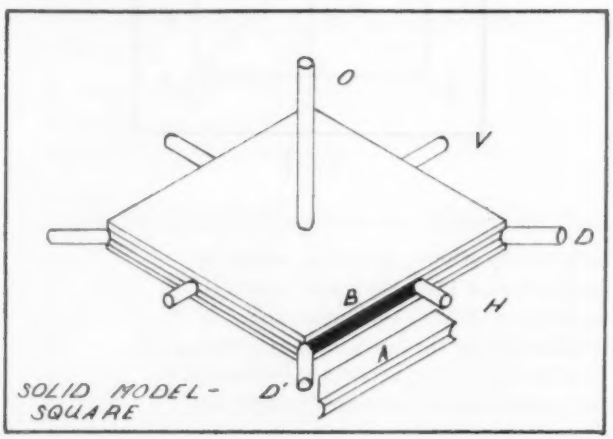

Fig. 3

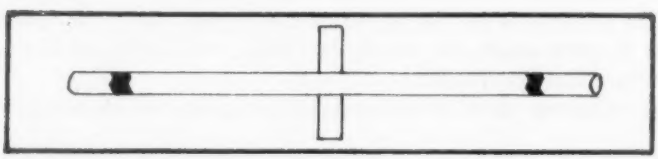

Fig. 4

After I had constructed the solid models, I started my "working" models. I first cut out four copies of the figure I was working on, that is, the square or the circle or the triangle. Then I glued these four pieces together to form a solid figure $\frac{1}{2}''$ thick. Next, I bored a $\frac{1}{4}$-inch hole through the exact center of the model. I then cut out spaces, or grooves, through three layers of the four-layer figure, so that all the operations could be performed without removing the main axis—the only axis in each of these models. Grooves for the axis of the working model of the square are indicated by the darkened area *A*, Fig. 5. I cut grooves on the opposite side of the model, indicated by dotted lines, *B*, in Fig. 5, so the movable axis can rotate into all the positions and still lie between the outer faces of the figure, giving the effect of the axis' passing through the figure as in the solid model. I made the grooves about $\frac{5}{16}''$ thick so the axis would lie without binding.

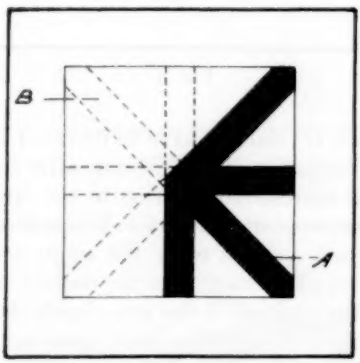

FIG. 5

In constructing the cube, the regular tetrahedron, and the tesseract, I made the solid figures first; then I added the axes. For the cube, I first cut out six squares as nearly identical as possible and glued them together to form a cube. I bored $\frac{1}{4}$-inch holes through the exact center of the six faces and through four of the corners, indicated by *A*, *B*, *C*, and *D*, Fig. 7. I inserted $\frac{1}{4}$-inch dowels in the appropriate places to represent the axes. I constructed the regular tetrahedron and the tesseract similarly.

The construction of the working models of the cube, the regular tetrahedron, and the tesseract was more difficult than the other working models I had made. I finally constructed a cube and then inserted a working model of the square inside it. (See dotted lines, Fig. 6). This central piece was made exactly like the square except

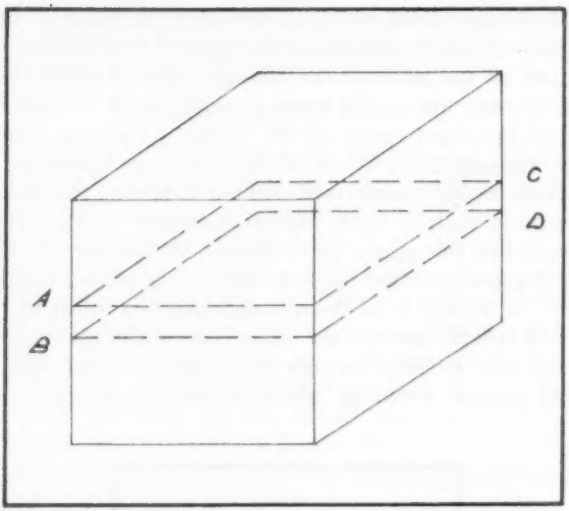

FIG. 6

the diagonals, D and D', did not have to be cut. I then cut two faces of the cube in a T formation (Fig. 7). Next, after cutting out areas 1, 2, and 3, I cut out corresponding areas in the opposing faces. (For instance, 1 and 4 are opposites, Fig. 7.). When all of these parts had been cut as described, I could move the single axis (Fig. 4) to the five defined positions. (This eliminates the confusion of having several axes present, and the position of the axis clearly demonstrates which axis the operator has in mind.) The short cross-bar on the single axis rests inside the cube and keeps the axis from falling clear out.

When working with the regular tetrahedron, I found it easier and more convenient to make an axis with a long cross-bar than to make a working model of the triangle and place it inside. I first made a regular tetrahedron and then cut grooves in the faces of the figure so I could move the axis to all of the defined positions. My final model was the tesseract (Fig. 8). I made two working models of the cube and connected them with projections (striped area, Fig. 8). I cut the faces of this model so I could move the axis to all the defined positions. To perform all the movements on this model, I have to remove the axis after some of the movements and re-insert it to complete the movements. (Some of the points through which the axis passes cannot be connected by axis grooves; to put in such openings for the axis, I would have to cut my model in two.) To my knowledge, this treatment of the tesseract is not shown in any book.

To finish the models, I painted the outside of the figures white. I

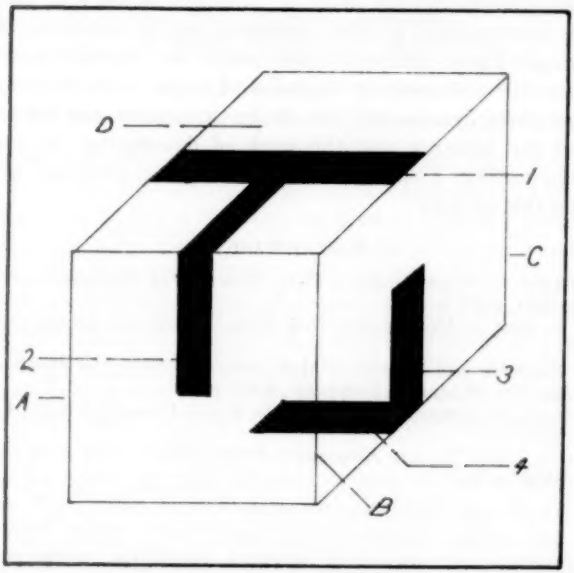

FIG. 7

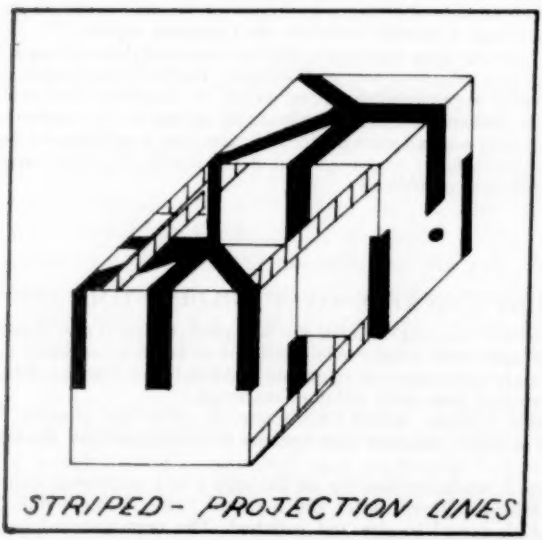

FIG. 8

painted all grooves and the axes, up to ½ inch of the end, black. The ends were each painted a color corresponding to one of the elements of the group. These different colors make the multiplication tables more attractive and easier to visualize. I made multiplication tables for the first three figures only (the circle, the square, and the triangle).

I found the research and the work of developing the models of groups fascinating. I spent much of my spare time for about six months on this project.

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FLUORIDATION OF PRIVATE WATER SUPPLIES NOW POSSIBLE

A method by which fluoridated water can be supplied to the 60,000,000 persons in the United States who are served by private water systems such as wells has been reported.

The method consists of either a hydraulic or solenoid-actuated basement installation that feeds a fluoride solution into the water supply.

Such a method has been developed and has been used during the past two years in four homes in a suburban area of Maryland. Each of these homes is served by individual wells, approximately three inches in diameter, delivering between three and nine gallons of water per minute by means of a jet pump.

Experience with such a feeder device indicates that a satisfactory fluoride level can be achieved in home water systems if the installations are properly maintained and adjusted periodically.

NEW LIGHT CONCRETE SAVES BUILDING TIME AND MONEY

A new concrete building material can be sawed, chopped and chiseled without losing its strength, and weighs only one-third as much as ordinary concrete.

The new material is expected to enable builders to erect houses 40% faster and at 20% lower cost than with ordinary materials.

The cellular concrete, called Calsi-Crete, is easier and cheaper to ship and handle than ordinary concrete slabs because of its light weight, the manufacturer claims.

Calsi-Crete is made by blasting air through a wet mixture of concrete, silica, wood and asbestos fibers. After the material "rises," much like bread, it is molded, baked, sawed to size and polished. The new material is particularly suited for use as roof slabs, floors, walls and cores of doors.

A major property in addition to light weight and fire resistance, is that it will not chip during transit.

Antoine Laurent Lavoisier: A Study of Achievement*

Gordon E. Noble

Kalamazoo Central High School, Kalamazoo, Michigan

Lavoisier, the crusader of modern chemistry, was born in Paris, August 26, 1743. The setting of his birth was neither of royalty nor peasantry. His father, a wealthy tradesman was descended from a family that had gradually but surely brought prominence to the name Lavoisier. His grandfather had been postillion in the service of the king in the great forest section fifty miles east of Paris called Villers-Cotterets. It was here that young Antoine would grow up. During his life Lavoisier would never forget the solace that the Villers-Cotterets would endow upon him. The great forest would beckon him time and time again to tread the ground where his esteemed ancestors lay.

Father Lavoisier gave his son an excellent education at the College Mazarin. His studies were in law, but his heart was in science. His sympathetic father understood. Antoine would adopt the career of science. Upon leaving college Antoine devoted himself to scientific study with amazing application. The work of Lacaille, the astronomer and mathematician, interested him. He worked and learned in the laboratory of the great chemist-demonstrator Rouelle, and was stimulated in botany by Jussieu. He isolated himself from society and even restricted himself to a diet of bread and milk, so that he might apply himself without interruption to his scientific pursuits.

The Academy of Sciences was offering a prize for an essay on the best method lighting the streets of Paris. So that his eyes would be very sensitive to the work before him, he remained in a dark room for six weeks experimenting on all sorts of lamps. The results of his intense work won for him a gold medal on April 9, 1776.

Many subjects now embraced his interests. He analyzed gypsum and understood its nature. He accompanied the great French geologist, Guettard, through the country and then helped to construct the first geological map of France. Knowledge gained through this experience enabled him to write his first scholarly paper entitled "Mémoire sur les couches des montagnes." In a special type reflux distilling flask called a pelican he boiled water for 100 days. Through his careful weighings of equipment and materials before and after and his masterly analysis, he was able to refute before the Academy

* Chemistry Editor's note: Each fall many high school students get their first introduction to chemistry through a study of oxygen. It is hoped that this article may prove of value as a means of enriching the high school course. Mr. Noble prepared this paper while enrolled in a course at Western Michigan University, entitled "The History of Chemical Theory."—GERALD OSBORN

of Sciences the prevalent error as to the conversion of water into earthy material. With the balance he showed conclusively that the weight of the water had remained constant throughout the entire distillation; that the weight of the solid particles which settled out at the bottom of the pelican during the distillation was equivalent to the weight lost by the glassware throughout the experiment. He therefore concluded soundly and scientifically that the action of water on glassware would cause undissolved silica particles to settle out. To settle the much debated problem he was doing the one thing that those before him had failed to do. He used a balance. Lavoisier believed that in chemical analysis the most careful attention must be paid to weight. In this respect his craftsmanship was unique. In reforming chemistry Lavoisier contributed no real discovery, but his fame rests on the first precept of the science—the law of the conservation of mass. Chemical analysis must be quantitative. A chemical reaction must take on the form of an algebraical equation.

He became associated with the Academy of Sciences in 1768 and later was elevated to the position of president of that famed society. Lavoisier, serving very ably in that post, was carrying on an extensive reorganization of the Academy when the early actvities of the French Revolution caused it to be disbanded.

In 1769, Lavoisier became a farmer-general of the revenue. His compensation from this position would add to the resources already at his command for the advancement of science and to keep him and his young wife, Marie Paulze, in comfortable circumstances for the rest of their lives. Little did he realize what a costly position he had accepted. It was this association with "la ferme generale" that caught him in the mad frenzy of the French Revolution and carried him to the guillotine at the prime of his life, the age of 51.

The many pneumatic discoveries of Black, Cavendish, and Priestley which began to appear on the scene after the year 1770 challenged the intuitive mind of Lavoisier. Through his talents these important discoveries were to become links in a carefully ordered chain of chemical doctrine. The discoveries were made by other chemists. But their significance was never understood because the chemists who had done the discovering drew conclusions on the basis of the overpowering phlogiston theory so highly respected at that time. Lavoisier would carry out these experiments to satisfy his own curiosity; he would see their significance in a new light. With penetration and precision his mind would interpret correctly the conclusions he reached. Conclusions which did invalidate the conclusions of the men who had made the discoveries. Chemistry was going to become a science logical in form and coherent in expression.

Lavoisier could not confide in the theory of phlogiston. He sus-

pected it from the very beginning of his scientific career. He pondered over and over in his mind the same problems that had intrigued Boyle, Hooke, Mayow, and Rey. His attempt to solve these problems, however, centered upon careful weighings of all materials. Phosphorous absorbs air and increases in weight when it burns. Its water solution is acidic. Tin increases in weight and absorbs air when it burns. Lead calx heated with charcoal forms lead. A decrease in weight is noted. Black's fixed air comes off. His earliest conclusions on oxidation were submitted in a sealed envelope to the Academy of Sciences on November 1, 1772. More information was needed before the paper could be read. But Lavoisier wanted to make sure he received the credit of priority.

In the fall of 1774, Priestley, the experimenter, visited in Paris with Lavoisier, the theorizer. He told of his great discovery—that of dephlogisticated air. He told of the wonderful properties of this purest of all "airs." Priestley was content to have discovered this "air." He would go no further in understanding its significance. Lavoisier would find later on that Priestly's discovery would give him the answer to his own riddle. It is doubtful that Lavoisier saw immediately the importance of this gas in his own ideas. It was somewhat later before he repeated Priestley's experiment. Then he began to ponder. By heating mercury in air the bright red precipitate of mercury could be obtained that Priestley had used in his famous experiment. Apparently the precipitate was formed by uniting with something in the air. He set up a very unique experiment to prove his point. In a piece of glassware called a retort a weighed amount of mercury was placed. The opening in the neck of the retort was placed in a confined volume of air. For twelve days the mercury was subjected to a moderate heating. Shortly he noticed the flakes of the red precipitate forming in the retort. The volume of the air was decreasing as indicated by the rise in the level of the water over which the air was confined. After twelve days the remaining air was tested with a lighted candle. Very quickly it flickered out. Lavoisier reasoned that some gas which was a component of the air had united with the mercury to form the red precipitate. The next step was to weigh the red flakes. He did this very carefully. Then with violent heating the red flakes gave up the strange and marvelous gas that Priestley had discovered earlier. This was surely "air éminemment pur," (this was Lavoisier's first name for oxygen). A candle would flame brightly in it. And when this gas was mixed with the other gas which would not support combustion, Lavoisier would have ordinary air again. From these experimental results Lavoisier concluded that the mercury had initially united with this certain gas in air to form the red precipitate. On stronger heating it had given off this gas.Thus,

common air was made up of two gases; one which supported combustion, the other, inactive. He continued his experiments in combustion. He was beginning to understand its very nature. When he burned up sulfur and phosphorous, their water solutions would be acidic. This gas in the atmosphere—this purest of all airs—had the chemical power to form acids. Lavoisier named this gas oxygen from the Greek words meaning acid-former (Oxus—acid, Gennao—I beget). The inactive gas in the air received the name at first of azote; later it was called nitrogen. The conclusions that Lavoisier reached explained combustion as the chemical combination of oxygen with a combustible substance. Lavoisier had proved that there was no such thing as phlogiston—the elusive "fire-making" substance that held chemistry in its power for longer than a century. A substance increased in weight when it burned because oxygen had weight. No longer would the product of this chemical combination be called a calx. It would be called an oxide. The phlogiston theory would crumble along with its unstable terminology.[1]

Lavoisier now thought he knew, moreover, what took place when animals breathed. The oxygen was taken into the lungs, then into the blood stream along with dissolved food materials, where slow combustion was promoted and the life processes maintained. He was almost accurate in this interpretation. This later drew Lavoisier into a study of physiology. He was performing a notable experiment on respiration and perspiration, trying to learn more about life processes, when, ironically enough, he was hauled away from his work to be tried, sentenced, and deprived of his own life—a victim of the French revolution.

Lavoisier had heard of the interesting experiment that the English chemist, Cavendish, had performed. Cavendish had discovered an inflammable gas which, when combined with oxygen would produce water. In his laboratory in Paris Lavoisier repeated the experiment and verified the results of Cavendish. From the time of Aristotle water had supposedly been an element. But it was really a compound. Since oxygen is an acid-former, water should be an acid. This part of Lavoisier's theory was wrong. He had concluded incorrectly about the acidifying principle of oxygen, for oxygen is present in bases as well as in acids. His oxygen might better have been called hydrogen, the name Lavoisier gave to the inflammable gas of Cavendish after he learned that when it burned it formed water. Hydrogen which is the acidifying principle of all acids should have earned the name oxygen.

Cavendish had discovered hydrogen, but he thought it was phlogiston itself. Believing in the phlogiston theory, he concluded that

[1] Sidney J. French, *Drama of Chemistry* (New York: The University Society, 1937), pp. 28–30.

water was composed of phlogiston and "dephlogisticated air." He was right. But it was Lavoisier who gave the correct interpretation to Cavendish's clouded conclusions. Lavoisier had found the answer. This mysterious inflammable was not phlogiston; it was an element. When metals were treated with acids, hydrogen would be evolved. It came from the water that the acid was dissolved in, not from the metal; the other component of the water, the oxygen, united with the metal to form an oxide. This was what apparently caused the increase in weight. So Lavoisier believed. Although this interpretation was wrong, it gave support to his oxygen theory which, excepting the acid principle holds true now as it did them. However it was Lavoisier who showed what water is, not Cavendish. Credit can not be given be given to Lavoisier for the discovery of oxygen, hydrogen, or the composition of water, but he was the only man who could correctly interpret the significance.

Without giving due credit to Priestley and Cavendish and their discoveries, Lavoisier's doctrine overthrowing phlogiston took the form of a fully fledged theory in 1778. It was at this time that he formally introduced it at a "rentree publique" of the Academy of Sciences. Again, Lavoisier did not discover oxygen. But he named it, understood it, and pointed out its importance in the process of combustion. Priestley was too much the experimenter and not enough the theorizer to do this.

Surely Lavoisier, the theoretical chemist, ranks as the father of modern chemistry in this respect. Even Priestley had to share the honor of the oxygen discovery with Carl Wilhelm Scheele, the Swedish apothecary. Like Priestley, Scheele was glued to the theory of phlogiston; he would never understand the gas that he had independently discovered and appropriately named "fire-air".

Lavoisier's striking analysis of water and the synthesis of carbon dioxide—"fixed air," as it was commonly called, paved the way for a greater understanding of organic as well as inorganic substances, and the era of phlogiston came to an expected end with the publication of *méthode de nomenclature chimique* in 1787.

Chemistry which had been an art for so long was now reorganized on a modern scientific basis. With so much alchemistic jargon in the science, there could be no real meaning. The mysticism and magic had to be done away with. With the capable assistance of three contemporary scientists—Guyton de Morveau, the balloon builder; Anton Francois Fourcroy, the chemist-politico; and Claude Louis Berthollet, the chemist-teacher, Lavoisier developed a fine new system of chemical nomenclature. Words which would coherently express chemical data would be used. Adics were named from their acid-forming constituents other than oxygen. *Ic* and *ous*, denoting the

proportional amount of oxygen present, would end the names of the acids. A chemical compound consisting of only two elements would terminate in *ide* with the name of the metal first. The new terminology endured without change for almost fifty years, and has been necessarily altered from time to time to meet the needs of more recent progress.

There was not an immediate approval of Lavoisier's theory of burning. Its acceptance was hastened by the clear and consise form that Lavoisier gave it in his *Traité Elémentaire de Chimie*. In Paris, Laméthérie, the shining light of the Academy of Sciences, did not give in without a struggle. Berthollet led a reform that converted many. Most English chemists rallied to its support. Priestley and Cavendish, however, would never accept the new doctrine. In Germany, the birthplace of phlogiston, the reformation was long and arduous. By the end of the 18th century, however, the new chemistry had come of age. The adoption of the oxygen theory was almost universal.

The original idea behind Lavoisier's *Traité Elémentaire de Chimie* was to give vent to the new theory and the new nomenclature. The highlight of the book is his table of 33 elements. In complete accord with Boyle he defines an element as "a substance which cannot be further decomposed." He classified them according to four groups: the first is made up of the elementary gases; the second comprises those elements which, when oxidized, yield acids; the third includes the metals; and the fourth is made up of the so-called "earths"—silica, lime and magnesia. Since the *compounds* in the fourth group had never been decomposed, they could not be classified as anything but elements.

Heat and light are listed as elements also. Lavoisier did not believe that they were material substances, but since their appearance was associated with chemical change, he listed them as elements. Lavoisier, strangely enough, did advance the idea that heat was an invisible, weightless fluid that received the name caloric. What a pitfall in his achievements. Lavoisier, the great theorizer, sending phlogiston to an agonizing death and mollycoddling caloric. But Lavoisier's work was not with energy concepts. He dealt with matter-materials-substances.

Every element in his table found its position in the whole scheme according to its relation to oxygen. With the phlogistonists metals had been compounds of bases with phlogiston. With Lavoisier they became the elements which combined with oxygen to form bases. The non-metals were the elements which united with oxygen to form acids.

With all this, Lavoisier had led a gigantic and successful reforma-

tion. But this was not all. Guided by the principle that all substances must be accounted for by weight in a chemical change, he made an exact science of chemistry. His kind of experimentation and interpretation showed future chemists how to work.

Considering all that has been said, is it not then easy to agree that Lavoisier should be rightfully named the "Father of Modern Chemistry"? The English lay claim to the fact that the title belongs to Robert Boyle. Boyle was a brilliant man—of that there is no doubt. He was a capable theorizer, but he did not have the powerful analytical mind of Lavoisier. Boyle's definition of an element formed a strong basis for modern chemical theory. Coupled with lesser contributions, he has been hailed as the chemist who deserves the title. But Boyle did not offer experimental proof to give support to his definition, which therefore remained a mere intellectual idea. Furthermore he was unable to draw up a list of elements, which would have given impetus to his definition. In all fairness the title should go to Lavoisier. It was he who, using Boyle's definition, devised the first table of chemical elements. It was he who understood the discoveries of this time. His crafty experimental researches and his brilliant interpretrations helped him to erect the modern system of chemistry.

Outside the realm of science the activities of Lavoisier were just as conspicuous. As a farmer-general he sought and obtained the abolition of many unfair taxes, and he advocated a reduction of water in the watering-down process of tobacco for commercial use. Later he was unfairly charged of watering-down the soldiers' tobacco and decapitated because of it. He was given the directorship of the powder-works by Turgot in 1776. In this capacity he suppressed the searches for saltpetre in the cellars of private houses. He improved the manufacture of gunpowder. He sat in on different governmental assemblies. He was on the commission of weights, and measures, and in 1791 he became commissary to the treasury. He always worked for the good of the people; he developed a democratic type farm; he developed a systematic type of agriculture. He proposed a plan for developing a safe water supply for Paris. To quote the words of Lalande, "Lavoisier was to be found everywhere."

Those were the times when to be conspicuous was to be in danger. On May 2, 1794, Dupin accused the ferme générale of absorbing the nation's wealth." Lavoisier could not believe his life and activities might be in jeopardy. He sought refuge in a cellar thinking the clamoring would soon simmer down. Shortly he gave himself up feeling that he might be endangering the lives of his colleagues through his own behavior. But as fate would have it, he was caught up in the mad frenzy of the French Revolution. The Revolutionary Tribunal was stern. The ex-farmer-general would mount the steps of the guillotine.

Coffinhal, president of the Tribunal, was heard uttering the words, "The Republic has no need of scholars." Fourcroy was in a position to plead for the life of Lavoisier on the basis of his scientific achievements. He did nothing. Lavoisier was condemned as an opponent of the Revolution. On May 8, 1794, Lavoisier lost his life. M. Paulze, whose gifted daughter Lavoisier had married in 1771, was another of those unfortunate victims. Later France made amends; an elaborate funeral was ordained. Lavoisier, the greatest scientist France had ever produced must be remembered. Fourcroy, strangely enough, was the orator. He apparently wanted to justify his own actions during the entire bloody mess. From the mouth of Lagrange issued forth the statement, "It took them one moment to cut off that head, the like of which one hundred years will not produce."

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Traité Elémentaire de Chemie. Antoine Laurent Lavoisier

"LIQUID STRING" STUDY AIDS RESEARCH ON SYNTHETIC FIBERS

The problem of how to tie a length of "liquid string" has been solved, a scientist at the Johns Hopkins University reports.

One result may be better nylon stockings, dacron shirts and orlon sweaters. Synthetic fibers are liquid plastic compounds that are formed into threads by drying thin streams of the liquid.

A relatively simple laboratory apparatus has been set up that actually permits the observation of the tensions and other characteristics of a thin stream of liquid when it is "tied" at both ends.

The apparatus consists of a glass casing eight feet long and five inches in diameter, a slender steel nozzle and tube attached to a pressure system, an electromagnet that causes the flexible tube to vibrate at any given rate, and a camera equipped with high-speed electronic flash.

A heavy, viscous—or gooey—liquid, carboxymethylcellulose in water, is squirted out through the nozzle. Its action is stopped in mid-flight by using the camera's stroboscopic light.

So far experiments have shown that the liquid stream has some characteristics in common with a true string, such as a plucked violin string. It is composed of a variety of waves, has nodes and is affected by speed, the liquid's viscosity and the diameter of the nozzle opening. Results of the experiments may help to produce better synthetic fibers.

Manufacturers need better information on when the liquid stream used to make these fibers should be dried and how fast the drying should take place.

A Device for Measuring Understanding of the Meaning of Units of Measure

Joyce M. Burchenal

L'Anse Creuse High School, Mt. Clemens, Michigan

Several years ago when I taught my first course in general mathematics I was literally shocked at the lack of understanding of units of measure on the part of the students. I had expected to encounter difficulty in the study of the metric system, but the students' difficulty in handling our own systems of measurements which are used daily was appalling to a person like myself who had considered the handling of these concepts as routine.

The students had memorized the basic relationships, but could not apply them. They had not grasped the concept of the relative size of the units. Consequently, when they were required to change inches to feet, either multiplication or division was used, with no particular reason for the choice of process. To them an answer of 5 feet 38 inches was as good as 8 feet 2 inches. Their attitude toward problems of this type seemed to be to select the first process that came to mind, and the teacher would "decide" if you were correct or not. As practical as these problems were, they were unable to solve them because they did not understand the reason for using units of different size.

To aid the students in developing better concepts we measured the room in inches, feet, yards, and so many lengths of a knotted string, and compared the results. We discussed visualization of quantities expressed in terms of units of different size—180 minutes or 3 hours, etc. We discussed how a system of measurements is built up from small units to larger ones, that there are various systems of measurements, and the important thing is to discover the relationship between the units of measure in the system being used and then decide whether we are changing from a small unit to a larger. If we are changing from a small unit to a larger one we have to divide because the numerical size of our answer will be smaller than the original since the quantity has been divided into larger "pieces."

After I felt the students had grasped these concepts I desired to test their understanding. I therefore prepared this "space" story as the final test on the unit. The students were quite shocked when they received it, but quickly settled down to try to figure it out. Many wanted explanations of terms, but none were given other than what was in the story. Students were allowed to keep the story portion, but turned in the second sheet which was graded and returned to them.

Scores on the test were very good. Some students who ordinarily

did very poorly performed very well on this test. Others who normally did satisfactory work by means of rote memorization did not do as well when faced with a strange situation.

Students were asked to write their comments on the test. I think these comments tell of the effectiveness of the test better than any discussion I could add: "I thought it was worthwhile. It helped your mental ability and made you think." "I learned that no matter what language, if you know about what each figure represents you can work the problem you have." "I still have to learn to put things in lowest terms. It was a good test." "I learned to work with different units that I didn't know about before." "It was a good test for thinking out problems, although it was harder than working with regular measurements." "I learned that names don't make any difference in some ways." "It helped me in borrowing units."

This test has been given to succeeding classes by myself and other teachers, with the same enthusiastic results. Perhaps other teachers can use this technique for enriching their General Math course, as well as evaluating their students' comprehension of our system of measurements.

Adventures in Outer Space

Rocket ship Q.S.M. developed trouble in the atomic pile unit while en route on a routine flight from Earth to Pluto. It was impossible to warp from hyper-space drive back into normal in order to effect a landing on Pluto. The ship traveled aimlessly, the manual controls were useless, the astrogator was unable to determine the location of the ship. The crew of twelve was near panic after four days. They had no idea of their location, other than that they had left their galaxy and were somewhere in the Universe.

On the fifth day of their random flight, the ship lurched into normal drive. There was no reason for this just as there had been no apparent reason for the original failure to warp on the approach to Pluto.

Fortunately, a planet was in range. Since supplies were getting low the skipper decided to attempt planetfall in hopes that the planet supported life of some type, and feeling that at least some food supplies might be obtained. It was at least better than drifting aimlessly through space!

The landing was accomplished with slight injury to the ship; the crew was uninjured. Imagine their astonishment to to find that not only was the planet able to support life, but that it was inhabited by intelligent beings!

The people of the planet were not too different from those on Terra—the most noticeable differences were the light blue color of their skin, and the seven fingers on each hand. The crew members

quickly found that the air was breathable, the food edible, and the language similar to their own Intergalactic. It was not long before the members were friends with the natives. Mathematics, fortunately, is a type of interworld language, numbers and their use are constant in every civilization. The basic units of measure on Vallaacula, however, were different from those on Terra. In order to get the space ship repaired, it was necessary for the ship's chief engineer to learn the basic Vallaacullen units of measure and how to use them.

Here are the tables he made up for his use. If you were the engineer, could you solve the problems on the next page, using the tables given?

Linear Measure	vahm—smallest unit (similar to our inch) 14 vahms = 1 retem 8 retems = 1 droyh
Time	Rouh—like our hour—a division of a saed 29 rouh = 1 saed (like our day) 9 saed = 1 grulb (like our week)
Weight	zoon—smallest unit of weight 22 zoon = 1 bdaen (like our pound)

PROBLEMS

I. Add

a. 3 droyh 7 retem 13 vahm
5 droyh 10 retem 12 vahm

b. 5 grulb 20 saed 9 rouh
4 grulb 50 saed 8 rouh
6 grulb 48 saed 6 rouh

c. 4 bdaen 20 zoon
2 bdaen 8 zoon
7 bdaen 15 zoon

II. Subtract

a. 12 retem
9 retem 9 vahm

b. 3 grulb 20 saed 42 rouh
2 grulb 25 saed 50 rouh

III. Multiply

a. 6 retem 13 vahm
5

b. 22 bdaen 8 zoon
9

IV. Divide

12)29 droyh 14 retem 12 vahm

Answers:

I. a. 10 droyh 2 retem 11 vahm
b. 28 grulb 1 saed 23 rouh
c. 14 bdaen 2 zoon
II. a. 2 retem 5 vahm

b. 3 saed 21 rouh
III. a. 34 retem 9 vahm (or: 4 droyh 2 retem 9 vahm)
b. 201 bdaen 6 zoon
IV. 2 droyh 4 retem 8 vahm

A Demonstration Procedure for a Proof of the Polarity of Molecules

A. J. Hoffman
Eastern Illinois University, Charleston, Illinois

Visual proof that certain molecules are dipoles is not often shown to students by teachers of chemistry and physics. Sufficient apparatus is provided by an ordinary pocket comb, charged by rubbing on wool, and a small stream of water from a faucet. The water stream is easily deflected toward the charged comb. The stream may likewise be deflected by a glass rod charged by rubbing it with silk.

To prove that this is characteristic of polar molecules one selects a number of liquids such as carbon tetrachloride, alcohol, gasoline, acetone, and allows them to flow successively from a separatory funnel* in tiny streams. The amount of deflection is plainly seen to be a function of the polarity of the molecules of the chosen liquid.

An interesting sidelight is afforded by testing the attraction of the charged body by solutions of electrolytes where further ease of deflection is noted. Try approaching a hanging drop of salt water with the charged comb. The result is remarkable. Students of organic chemistry can, by a series of such demonstrations, come to realize why some organic molecules can become so positioned electrically that reaction can rather easily occur. The demonstrations described are easily as potent a tool for the understanding of polarity as the familiar conductivity of ionic solutions is to an understanding of electrolytes.

* A burette may be used in place of a separatory funnel.

HALLEY'S COMET FIRST RECORDED BY CHINESE

Chinese astronomers spotted Halley's comet in 66 A.D.

This is the first recorded report of the comet, which comes close to the earth every 75 years. The information that Chinese astronomers spotted the comet nearly two millenia ago, and again in 684 and 837 A.D., is contained in a compendium and translation of ancient Chinese astronomical observations by Dr. Hsi Tze-tsung of the Academia Sinica of Peking. The compendium has been published by the Smithsonian Institution.

Following the Chinese observations, the next recording was made in Europe in 1305. The recurrent comet was last seen in 1910, at which time, the Institution says, it caused "predictions that its tail might lash to earth, perhaps bring an end to all life."

Symposium on Recent Research in Science Education

George G. Mallinson, Editor

The following series of papers consists of the reports presented at the Symposium: Recent Research in Science Education, sponsored by the National Association for Research in Science Teaching at the Fourth Indianapolis meeting of the American Association for the Advancement of Science. The presentations took place at 9:30 A.M. in the Monte Carlo Room of the Hotel Continental on Friday, December 27, 1957.

The reports covered the reviews and implications of recent research in science teaching at the elementary, secondary and college levels.

SURVEY OF RECENT RESEARCH IN ELEMENTARY-SCHOOL SCIENCE EDUCATION

Jacqueline Buck Mallinson

Western Michigan University, Kalamazoo, Michigan

Introduction

The material for this survey was obtained by searching indices of published literature, and lists of unpublished master's and doctor's theses for the period January 1956 through August 1957. A total of thirteen studies that met the ordinarily accepted criteria of research were thus located. The search also brought to light a vast number of discursive and expository articles of varying degrees of merit.

It might be stated at the outset that the amount of research in the field of elementary-school science education is small indeed. Further, the research techniques used in many of the studies is shoddy and the problems investigated are, in many cases, of relatively trivial significance. Some of the studies presented in this summary are also open to a number of the criticisms implicit in the above statements. However, they were included because of the dearth of material available.

Findings

What Is the Status of Elementary-School Science Teaching? A problem attacked perennially deals with the conditions obtaining in the elementary science programs. Two studies were found that dealt with the status of such programs in restricted geographical areas. The findings served only to support the well-known facts that: 1) the elementary-school science program is far from established in

many schools; 2) the science training of elementary-school teachers tends to be meager and relatively narrow and specialized, rather than generalized; and 3) elementary-school science is usually taught with little or no equipment and with little or no time available for the teacher to prepare demonstrations.

These studies do point out the fact that elementary teachers profess general agreement with the statements of authority as to the desirable aims and outcomes of the elementary science program, and agree that science should be an integral part of the total elementary-school curriculum. It was indicated also that a number of supervisors and administrators believe that there is a definite trend toward more successful teaching of science in the elementary schools.

However, one recent conclusion tends to contradict findings from certain other studies, namely, that teachers take advantage of in-service programs. Other studies point out that in-service programs have not been attractive to elementary-school teachers in so far as attendance may be a criterion.

What Is the Status of Teacher Education for Elementary-School Science? There seems to be an increasing interest in evaluating the training of teachers to teach elementary-school science. Although only two studies were found during the chronological period encompassed by this summary, they do add emphasis to a number reported in previous years.

An analysis of the offerings of teacher-training institutions, both public and private, indicates that the majority offer courses in science designed especially for elementary teachers. The percentage of public institutions with such offerings is, however, greater than the percentage of private. In addition, nearly all of these institutions offer a methods course in science for elementary teachers. However, it was pointed out that such offerings are seldom extensive enough for an academic minor or major. It was found that most of the courses taken by elementary teachers are those available for specialists in chemistry, physics and biology. Further, it was indicated that offerings for elementary teachers in geology and astronomy were seldom available.

The findings showed strong sentiment on the part of teachers and administrators for the development of programs for training specialists for teaching elementary science. It was suggested that such programs would require courses different from those now available in the sciences for elementary teachers.

All the studies pointed out the need for in-service programs for helping elementary-school teachers do a better job of teaching science. The need was asserted by persons at all levels of education. Further,

teachers indicated that they would like to have such in-service experiences available to them.

Yet, the studies fail to indicate that student achievement in elementary science is appreciably greater in classes taught by teachers who have had the opportunity to participate in in-service programs. Also, there seems to be confusion as to what should be included in an effective in-service program.

Hence, it may be stated that much research needs to be undertaken to determine the optimal types of pre-service and in-service experiences in science for elementary-school teachers.

To What Extent May Principles of Science Be Taught at Certain Grade Levels in the Elementary School? One of the major problems of elementary science concerns the grade placement of certain areas of science and certain principles associated with them. Although a great number of studies have been undertaken with respect to this problem. (and more recently, summaries of the earlier studies), the findings are still inconclusive.

If certain criteria of understanding and achievement are postulated, then subject-matter areas and principles can apparently be assigned to certain grade levels at which they can be taught most effectively. However, if no particular criterion of achievement is pre-determined, then the findings of research tend to be most inconclusive. Apparently given levels of understanding and of achievement condition the grade-placement of a science topic or principle far more than does the nature of the subject-matter area with which a topic or principle is concerned.

The problems related to grade placement, however, still need much study.

What Efforts Are Being Made to Vitalize the Curriculum in Elementary Science? Three studies undertaken during the period indicated dealt with efforts to identify modern aspects of subject-matter appropriate for inclusion in elementary science and to determine the extent to which problem-solving objectives may be taught successfully in the elementary science program.

The first two studies dealt with the possibilities of using elements of nuclear energy and ecology in elementary science programs. Ordinarily both of these areas are considered to be within the realm of secondary-school science. However, in both studies cited materials from these areas were adapted for the learning levels of elementary children. Specific efforts were made to ascertain their previous experiences in the fields and to determine the questions they wanted answered. Extensive use was made of enrichment techniques such as films, field trips, outside lecturers, and demonstrations. With both

fields of science the students showed great gains in knowledge and concepts in the respective fields, as well as increased interest in them.

These studies seem to show that materials ordinarily of high-school level can be taught successfully in the elementary school *if* properly modified.

The other study attempted to determine, using an experimental technique, whether distinct efforts to teach students to identify and evaluate scientific assumptions resulted in significant increments in this ability.

In general, the study supported what has been recognized for some time. Namely, objectives—both of the subject-matter type and the problem-solving type—can best be accomplished when the teaching efforts are specifically oriented. In general, objectives that are taught only incidentally are less likely to be achieved.

All these studies, together with numerous ones previously undertaken, indicate that if specific efforts are made, and the material is modified to suit the learning level of the student, practically any objective of science teaching can be attained at a given level.

From What Sources Do Elementary Students Receive Their Science Information? Only one study was discovered in this area but it was considered sufficiently novel to include here.

Children at the first and second grade levels in a large city were interviewed individually. During the interviews various common areas of science were discussed. The children were then asked to identify the sources of information for their comments.

The students showed wide knowledge of their physical environments, although the knowledge differed greatly in degree and kind with the various youngsters. Most of the information they communicated during the interview was reported to come from direct experience with the science areas discussed. The "indirect source" of information that seemed most fruitful was the parent. It was interesting to note that only ten per cent of the scientific information was reported to have been obtained from school experiences.

What Has Research Shown About Science Materials Written for for Elementary-School Children? One study dealing with the use of analogy in science writings for children, and two dealing with the measurement of reading difficulty of science materials were located.

The first dealing with analogy was a historical study designed to analyze the trends in the use of analogy in science books written for elementary children from 1800–1952. The aspects analyzed were: purpose and complexity of the analogy; and its nearness to a child's experience.

The findings revealed that the use of analogy was quite common

and that the analogies were generally within the experiences of the children. However, there was no evidence that the use of analogy had changed markedly during the period encompassed by the study.

The other two studies sought to compare the consistency of the estimates of reading "experts" and elementary teachers of the level of reading difficulty of elementary science materials, with the consistency with which the reading difficulty of the same passages was measured by three different reading formulae.

Suffice to say, nearly two hundred passages were submitted to measurement by the Lorge, Flesch, and Dale-Chall formulae; and also to the inspection of a number of reading experts and teachers.

In general, the measurements of the reading formulae were highly consistent, the differentials in measurements averaging one year or less. However, the abilities of reading experts and teachers to estimate from inspection the reading difficulty of elementary science materials is highly suspect.

The findings indicate that differentials among the estimates made by reading experts average more than two years and those of elementary teachers more than three. The evidence strongly suggests, therefore, that the use of reading formulae for determining reading difficulty of elementary-science materials is justified.

Summary

A "summary of a summary" would, of course, be redundant. However, in light of the quality and quantity of the current research investigations in the field of elementary science, a few recommendations seem justifiable.

First, it is obvious that a great deal more research needs to be undertaken in this field before many of the major problems can be solved. At the present time, a very small percentage of the investigations in the area of science education are devoted to the elementary-school level.

In addition, it would appear that more "second level" studies need to be conducted. In the past, most of the research has been concerned with surveys of current practices and with analyses of various forms of written material related to the teaching of elementary science. It is clear that such research has now well established the "status" of elementary-school science.

Hence, it would appear that future research studies should go one step farther and investigate some of the techniques and methods that may best be *applied* in the solution of the major problems recognized by elementary science educators.

IMPLICATIONS OF THE FINDINGS OF RECENT RESEARCH IN ELEMENTARY-SCHOOL SCIENCE EDUCATION

Muriel Beuschlein

Department of Science, Chicago Teachers College, Chicago, Illinois

From the foregoing survey of recent research in elementary school science education it is readily apparent that there is urgent need for research that will provide answers to current, critical problems and for direction which will give guidance toward the improvement of science teaching.

Considering the implications from that which has been reported, we can conclude that a limited number of status studies are purposeful in delineating weaknesses and inadequacies only if steps are outlined for the implementation of improvements or means to strengthen the imperfections. Having recognized the deficiencies and wide variation in elementary school science programs and in the preparation of teachers for these programs, research efforts could be directed toward the solution—investigation of necessary components for an effectual elementary school science program, what constitutes adequate teacher preparation for this subject area, and what successful inservice courses can be established.

From conversations with supervisors and administors it appears that the most urgent need continues to be teacher preparation. During these times it is especially critical. More advanced science courses may be the answer but again there is considerable evidence that understanding of basic science concepts and their application to daily experiences is not always developed by advanced work nor is it the purpose of these courses. In the experience of many teachers of science methods, with both inservice and preservice teachers, many students lack adequate understanding of the elementary science concepts even though they have had college work in the physical and biological sciences and therefore are handicapped in helping pupils gain an understanding.

We need to consider at this point the quality of teaching, the ability of the teacher to help the children understand rather than to memorize facts, and also the teacher's understanding of principles at the pupil's level and in terms of everyday experiences.

Perhaps these problems are too comprehensive for a single investigator or for a doctoral dissertation. Perhaps the traditional pattern of research does not lend itself to studies of this nature. It might be more desirable to seek solutions on a team basis with investigators in different areas working together on one aspect of the problem. Per-

haps we need to consider more carefully the function of research in this critical period. We are aware of current trends with their expected pressures. It may be imperative that more workers pool their efforts to bring results of broader scope and significance.

We might also consider the lag between research findings and their application in the classroom situation. We do not have time to wait for a gradual filtering down of new ideas and solutions to our problems.

Selection and grade placement of scientific principles continue to be a concern of the curriculum workers and authors of texts as well as classroom teachers. Review of current practices, curriculum guides and teacher opinions provide inconclusive evidence on which to base selection of principles for a specific grade. Instead we need to know how much we can teach and how far we can take our pupils. It is necessary to consider the limiting factors and how to overcome them. Also we must consider how to overcome the restricting effect on science teaching when reading vocabulary lags far behind capacity to understand and to discuss.

Have we sufficiently considered the out-of-school science experiences of our pupils and the impact of TV programs? Have we adequately recognized that the children are watching, listening and learning about things of science which are, in many cases, far beyond the science classroom program? What are the best ways to utilize these out-of-school influences to supplement or improve the regular program? This research should tell us.

The common expression "a flexible framework that meets the needs and interests of children" means a number of things to different people. Perhaps there is much more to be learned regarding the "scope and sequence" of a science program. The variety of science curriculum designs, from a completely flexible program based on a child's curiosity to the continuous, integrated 9 or 14 year program, indicates differences of opinion which might be further investigated and would include the problem of continuity which concerns many teachers and administrators.

From studies of children's interests, contradictory conclusions have been drawn. It is possible that investigations might take the next step . . . what can be accomplished by utilizing or extending these interests or what experiences operated in their selection of interests. It might be profitable to follow up the interest inventories to discover the extent to which interests affected career selection, the lasting quality of these interests, and their influence on the science program. The question of correlation or integration of science with other elementary areas perennially appears in unit development. No further investigations are noted since 1950. In view of current emphasis on

science this indicates another area of inquiry. Does science make its proper contribution to the other phases of the elementary program?

Two aspects of the elementary science program seem to need considerable investigation if these are to give direct help to teachers. First, there is the ever present issue of the development of techniques for problem solving. Much has been written in this area but teachers continually need to be convinced, assured, and more adequately guided in using procedures providing this development. It may be a question of the lack of the teacher's experience in problem solving. The extent to which the entire elementary program provides opportunities for critical thinking and the gradual increase in ability may be accepted by most teachers but many need direct assistance in proceeding in this direction.

The second concern is the matter of evaluation. This, too, has been widely discussed in the literature but the recommended techniques such as behavior journals, interviews, and observations are time consuming and too involved for teachers with large classes, especially in school systems using letter grades. It is here that the inevitable objective tests of content material provide almost the sole criterion of success of a program. Evaluation in terms of carefully selected goals and objectives is neglected. Achievement is assumed from the number of correct responses to a true and false test or a matching exercise. The understanding of scientific principles, the development of problem solving techniques, the ability to see cause and effect relationships, changes in attitude and behavior are not measured by grades on an examination paper when these are mere samplings of recognition of limited facts. If many are restricted to the use of objective tests because of large classes and heavy programs then further study might reveal more effective types of tests to determine the rate of growth in problem solving ability and the understanding of science principles. Development of evaluative instruments is not automatically achieved.

Summary

Briefly stated the following questions need urgent consideration:

1. What steps can be taken to provide an adequate content background for all teachers of elementary science?
2. How can we develop and evaluate growth in understanding of science principles and ability to do critical thinking?
3. What can be done to help teachers become adept in using problem solving techniques with elementary pupils?
4. By what means can we more readily incorporate pertinent research findings into actual practice?

5. How can we "step up" research in elementary school science and increase its scope and significance?

SURVEY OF RECENT RESEARCH IN SECONDARY-SCHOOL SCIENCE EDUCATION

Herbert A. Smith

University of Kansas, Lawrence, Kansas

In the span of 15 minutes it would not be possible to review all of the recent research that has been done related to secondary school science. Thus, my presentation will be based upon a selection of studies from those which are available. I have chosen to divide my review into six sections; general education, junior high school science, biology, chemistry, physics, and the gifted student in science.

General Education

Efforts continue to determine the place of general education science, appropriate methods, and content of courses designed for general education. Efforts are common to make the traditional science courses more functional in terms of contributing to general education objectives.

There seems to be a trend toward more general education courses, particularly those replacing chemistry and physics in the public schools especially for non-college bound students. There is also a trend for educators to become more cognizant of the value of general education for those not becoming scientists. Most schools permit general education courses to be counted as a science major subject to fulfill graduation requirements. About 76 per cent of the courses include laboratory work, and the courses are less likely than formerly to be regarded as courses for the slow learner. In general the objectives to be attained are those related to a broad and integrated understanding of science and its place in modern society and the achieving of some understanding of scientific method and the process of critical thinking. Study has also been given to the manner in which a community using both school and lay groups can analyze the adequacy of its science progam.

Attempts to identify principles of science for general education continue. One study on principles of earth science of significance for general education was reported.

Junior High School Science

Principles as objectives of instruction received attention at this

level of education. Two hundred fifty-three principles were identified which were believed to be desirable for inclusion in general science. Some inquiry was also directed toward trying to determine whether certain experiments might best be done as demonstrations or whether they might be more suitable as individual laboratory experiences. It was found that most experiments can be performed with relatively simple apparatus and it was indicated that more individual laboratory was feasible and should be provided for general science courses.

In another study current events of science were employed to try to determine whether certain selected procedures in the use of such materials were effective in promoting the development of scientific attitude on the part of seventh and eighth grade boys. The results indicated that the procedures employed did develop, to some extent, a more scientific outlook on the part of students.

The role of assumptions in ninth grade science has also been investigated. Perhaps one of the most significant conclusions coming out of this particular study was the fact that teachers of ninth grade general science were not particularly sensitive to the assumptions involved in reaching or accepting certain conclusions.

One study was made in an effort to determine pupils' ability to use the scientific method of problem-solving and to develop and maintain scientific attitudes. The general conclusion was that seventh grade pupils do not naturally have scientific attitudes nor do they know how to apply the scientific method unless they are taught. Class organization designed to emphasize problem-solving activities did not result in a loss of subject matter understanding when the experimental group was compared to a control group.

Two studies on the history of general science were reported. One traced the development antecedent to the present general science course. General science was seen to incorporate the best practices from nature study in the elementary schools and the specialized sciences offered in senior high school. The other study concluded that there is less agreement as to methods and purposes of science in education than has existed previously.

Biology

Various aspects of biology curriculum continue to receive attention. A study has been made of the activities associated with important biological science principles which have been selected for their value to general education. In most cases it is apparent that there are sufficient laboratory-type activities which would be appropriate for developing an understanding of most of the important biological principles. About half of these seem to be more appropriate as demonstrations than as individual laboratory experiments. An-

other study revealed that students taught in classes where principles were stressed made more progress toward certain educational goals than students not so instructed.

The state of flux and present lack of clarity which exists as far as objectives for high school biology laboratory are concerned has been investigated. The teachers on whom the study was based appeared to be unable to distinguish effectively between objectives which are appropriate and those which are not appropriate for high school biology.

Evidence has also been submitted in two studies that much of the material found in various courses of study is obsolete and lacks adequate enrichment material and suggestions for instructional procedures, special aids to vocabulary development, evaluation, and laboratory procedures.

In biology, as in general science, the problem of interest has also been investigated. It was concluded that the selections of topics made by textbook authors do not coincide closely with the expressed interests of students. A study of the effects of the use of films on biological subjects in pupil achievement in biology was also made. Procedure in which principles demonstrated or illustrated in the films were stressed prior to the showing of the film resulted in superior learning.

Chemistry

Major emphasis in recent research on the teaching of chemistry seems to be focused on laboratory phases of the subject. One study has been reported in which it was sought to compare the learning in high school chemistry laboratory of students who were taught by an inductive-deductive approach as compared to the more conventional deductive-descriptive approach. Comparisons were made on the basis of achievement directed toward the following four objectives.

1. Knowledge of facts and principles of chemistry.
2. Applications of chemical principles to new situations.
3. Knowledge of, and ability to use, the scientific method and scientific attitude.
4. Performance in the laboratory.

For all objectives, differences were observed in favor of the inductive-deductive class. Statistical analysis revealed that significant differences existed with reference to knowledge of, and ability to use scientific method and attitude, and in ability to identify proper laboratory techniques. Test of retention also showed differences in mean scores favoring the inductive-deductive classes.

Another scholarly study appears in the literature in which a textbook centered approach was contrasted with the laboratory-centered approach to instruction. The investigation indicates that the dis-

tinction was a matter of "emphasis" rather than a matter of "abstraction." The experiment was conducted with "accelerated" and "non-accelerated" classes for each method. An examination was employed which measured recall of basic concepts, application of concepts and principles, and comprehension and interpretation. The findings were that the accelerated students increased in variance as a group regardless of the approach whether textbook or laboratory. The non-accelerated students profited more from the laboratory approach in as far as increase in variance of the group was concerned. This study suggested an important postulate of educational philosophy that greater variation in classroom achievement is indicative of better adjustment to individual differences among pupils during the learning process.

The perennial problem of the value of individual laboratory as compared to teacher demonstration has also received attention. An analysis reveals that confusion still exists relative to the merits of both methods, primarily because the criteria for comparison have not been uniformly applied. As a corollary statement it was significant that while numerous statements of objectives exist very few of them are specific relative to the manner in which they are to be achieved. Attention has also been given to "new" or improved demonstrations for teaching the principles of chemistry.

Some attempt has been made to determine the influence of high school preparation on achievement in chemistry in college. The results show that students that have had chemistry in high school were more successful in terms of grades earned than students not having chemistry. It was also pointed out that students with a background of high school physics and mathematics had lower percentages of low grades and higher percentages of high grades in college chemistry classes. Unfortunately, the question remains as to how much of this success is due to high school instruction and how much of it is due to other factors.

A study of opinions as to why chemistry is not offered in some schools revealed the following results. In order of frequency the reasons presented were: no community demand, too expensive, lack of room, no qualified teacher, insufficient value, and no time available in the curriculum.

In another film study it was revealed that sound motion pictures properly used do make significant contributions to achievement in chemistry.

Physics

One analysis of six standardized tests and the supplementary instructional materials in a standard high school physics textbook has

been made to reveal the extent to which the various objectives delineated in *The Taxonomy of Educational Objectives* are included. A general conclusion based on the analysis would be that the higher order objectives in the hierarchy established in the taxonomy are very inadequately represented in either the standardized test items or in the supplementary instructional material of the textbook.

The laboratory phase of physics instruction also seems to have received much attention as far as research investigations are concerned. One analysis of laboratory workbook and manuals in introductory high school physics courses has been reported. This was an attempt to determine to what extent individual elements of the scientific method were found in such instructional materials. It was concluded that most of the individual steps of the scientific method applicable in the high school physics experiments are included in manuals, but that not all of the steps are necessarily associated with any one experiment. The most serious omission as far as scientific method is concerned was the absence of a need for repeating an experiment. Steps of the scientific method are not mentioned specifically nor are they called to the attention of students. The manuals also neglect to include a discussion of scientific method or to point out clearly each step of the method as it may occur in various experiments. Another study sought to determine some simple projects which could be done in the high school physics laboratory. There seems to be considerable variation relative to the particular experiments that are done. The teachers participating in this particular study suggested a variety of additional exercises or projects which might be used.

One investigation sought to identify applications drawn from the field of aviation which might be employed to enrich physics courses. A summary of a physics course was made and applications or illustrations drawn from the field of aeronautics for teaching principles of physics were identified. In another phase of the study three types of guide sheets were developed. The first type was concerned with the construction of simple pieces of apparatus for demonstrating principles of aeronautics or physics. The second type was designed to aid in performing simple experiments or demonstrations pertaining to such principles, and the third type related to the direction of study activities to familiarize the students with aeronautical concepts or applications. There are innumerable applications which may be pointed out but unfortunately both teachers and pupils are not aware of the opportunities. There is a dearth of instructional materials providing for first-land experience as it relates to aviation.

One study sought to determine the number and type of mathematical terms needed to explain principles of physics. The area of

mechanics, as one might expect, required most familiarity with mathematics. There was a suggestion by the investigator that mechanics might be taught during the latter part of the course rather than at the beginning.

The Gifted Student in Science

After decades of relative neglect the gifted student as the object of special educational attention has become a popular concern. Accordingly, more and more investigations are making their appearance. One longitudinal series of studies has revealed some important factors in the training of gifted science students. A variety of techniques have been employed in making the evaluation including experimental and control groups, interviews, expert judgment, follow-up studies, observations, and tests. Perhaps among the more significant conclusions is the one that there is no shortage of talent but merely a shortage of opportunity as far as training the gifted students are concerned. The investigator has also identified four factors which tend to be associated with interest and success of students in science study. These factors are:

1. High intelligence of the type which results in success on tests of intelligence of mathematics, and of verbal skills.
2. Well trained teachers.
3. Opportunities for work in science.
4. Success in science over and above success in other intellectual endeavors.

Another extensive investigation has been made of provisions for outstanding science and mathematics students in selected high schools. A variety of techniques were employed in making a study. The major conclusions were that the selected schools made extensive use of organizational and extracurricular methods in providing for outstanding science and mathematic students. The degree to which various classroom methods were employed was affected by the length of the class period, administrative policies, ability groupings, and the nature of the subject studied. A number of specific conclusions were:

1. Superior students are victims of excessive demands on their time.
2. Homogeneous groupings can be used in all types of schools.
3. Such ability groupings should be based on several criteria.
4. Science and mathematics departments could undertake their own program for detecting and fostering the superior student.
5. Mathematics teachers were less aware of the possibilities for providing for outstanding students than were science teachers.
6. Methods found to be most widely used by teachers in the schools included in this study could be recommended for wide-spread use by all schools and teachers.

A study of students with dominant interests in science revealed that such students were in general: (1) superior in scholastic ability to the normal pupil, (2) tend to have hobbies involving physical

science, (3) have good social abilities and social behavior, (4) tend to avoid the usual physical activities found in typical secondary schools, (5) are readers of science literature, and (6) have been encouraged by parents or science teachers in their interests and hobbies. Two other studies of success of gifted students in science also emphasize the importance of cooperation and sympathetic understanding of teachers, particularly, the science teacher.

IMPLICATIONS OF THE FINDINGS OF RECENT RESEARCH IN SECONDARY-SCHOOL SCIENCE EDUCATION

Prevo Whitaker

Indiana University, Bloomington, Indiana

We are now passing through an unusual, though not a unique, time so far as science education is concerned. The everyday routine of civic and political life has been invaded and upset. The same state of aroused amazement and near-panic occurred during World War II when it became apparent that there was a show-down race among certain powers to produce the first atom bomb.

During these periods science becomes extremely popular. Scientific application cannot keep pace with the demands to accomplish more. Science instruction in public schools gets a terrific boost. Post World War II years have proved that most of this enthusiasm may be of a temporary nature; the rank and file of our citizenry, school administrators, and many government officials relaxed after we won the bomb race, and it appeared that technology in the United States was unmatchable.

However, not every front of our American way of life relapsed into complacency. The National Science Foundation continued to function as did a number of private endeavors to develop American science manpower in quality and numbers. So our foremost scientists and top government officials were surely not taken completely by surprise by Sputnik. The John R. Steelman Report to President Truman, dated October 10, 1947, was fourth in a series of five volumes which portrayed the national shortage of research scientists and engineers. In this volume the status of science education was surveyed, and where it was found wanting, broad recommendations were made suggesting further research efforts and more specific findings in the direction of recruitment of talent and improved teacher training in science from the elementary grades through graduate levels.

Thus, although Sputnik did not actually catch us with our atomic plants down, it did create enough furor to cause considerable political embarrassment. This furor has reverberated throughout America, including her schools. Therein, we are once more threatened, possibly, by the same impetuous motivation that aroused the public and caused a number of foolhardy activities in our schools during World War II.

That the type of science educational research that has been going on since the "cooling-off" period following World War II can effectively solve the problems of our scientist and engineer shortage today seems somewhat unlikely. Fortunately, in our research laboratories, basic research has continued, even though short-staffed. We have not been caught completely unaware of the realization that Russia has been surpassing us in scientific achievement; we simply have lacked the public support and willingness to admit the situation. Schools and their patrons have been complacent and a little amazed by the ominous warnings of people like Lewis L. Strouss, Chairman of the United States Atomic Energy Commission, who in his address, "Freedom's Need for the Trained Man," which was delivered before the sixth Edison Foundation Institute in November, 1955, said

> Too many of us have fallen into the easy attitude of assuming that the Russians, because of what we observed of the sinister purposes and slave methods of their political system and the compartmentalization of their research, could never match us in scientific initiative and progress.
>
> This was dangerous self-delusion. Actually, the emphasis which the Soviets are placing on science and particularly on the training of new young scientists and engineers, presents a real and growing challenge to us, and to the free world.

Dr. Reiner, who reviewed the educational research of a year ago said, "In general the volume of research has dropped sharply in the past years. Serious thought must be given to ways of encouraging and supporting research activities in science education at the secondary level." He implied further that from an evaluative standpoint many of the studies that were done were not of a nature likely to seriously affect secondary school science instruction, and so it seems to be in the case of research completed during the current year. While the individual projects cited by Dr. Smith are worthy in themselves, there do not appear to be many real efforts to meet the crucial issues.

Until teacher training institutions, public school administrators, and science teachers become aware of the crucial issues to the extent that research becomes the kind that can be implemented in their solution, the burden of improving science teaching will continue to rest upon the structures that have been created by industry, the federal government, and various extra-education organizations. The basic research dealt with in the days of the President's Scientific Research Board opened many avenues for further specific investigation.

Most of what has been done to stimulate better science teaching and to increase the quantity of science man power has come about through the action programs built from these studies. We hasten to acknowledge the fact that colleges and universities have cooperated in splendid fashion in a followership way by providing facilities and staff for these programs. Parenthetically, the action programs of the National Science Foundation, the Westinghouse Talent Search, state junior science fairs and science assemblies, and others are getting results. Numbers of physics and chemistry classes are slowly increasing in high schools. Teachers are receiving "shots in the arm" from institutes, fellowships, and direct help in their classrooms. This kind of growth is promising an effectual reply to the Russian boast. Let us hope that this orderly march does not get stampeded by another panicky citizenry or school administrative body; let us hope, on the other hand, that a more permanent public awakening has come to pass and that continued support of the action programs is in order. Aside from efforts to produce and train more of the science potential that is found in our schoolrooms, a great deal of planning to provide general education for all American youth has been done. When World War II ended, we were still disagreed on what should constitute a general education for everyone. "Everyone" means virtually just that so far as the secondary school is concerned. Except for those with mental or physical handicaps which make high school attendance impossible, and for a handful who leave high school before graduation, the rank and file of our American children find themselves one day in possession of a high school diploma. This fact, that children of a wide range of intelligence, background, and interests come into contact with each other in secondary classrooms, is often overlooked by the self-styled critic of education, who from his yesteryear outlook or narrow upper-class view, sees only the future of the bright and gifted pupils. If he could understand the problems of a secondary teacher who is faced by the conglomerate of his classes day after day, any discreet critic would carefully choose his words and avoid blanket charges as to the ineffectiveness of today's educational programs. It is true that constant improvement is needed. But it is a process that must grow with the task, and not one to be performed by some miracle panacea, such as "good old fashioned mental discipline" or "keeping the standards up."

What standards? Will we be able to establish standards, and maintain them, for all pupils? Or must we attempt the well-nigh impossible task of leading *every* individual to the limits of his educable potential? Yes, teachers must keep that as their goal, and they must do more. They must, by their own individual initiative and personality, find ways of inspiring each child insofar as possible to do his best.

They must do more, still. They must keep on trying new avenues of approach to Johnny, who can't read, and for Mary, who in the same class, has an I.Q. of 130 and a reading index equal to college sophomores. They must learn of methods tried and untried, and they must have time to do some research of their own. Teachers must also keep abreast of the content of their subject area, and above all be constant examples of what they would have their pupils become.

The contribution of science to general education and for the gifted alike, must be the inculcation of scientific attitudes, the eradication of fear of *science*, and an insight toward better living. Research along the lines of that described by Dean Smith *could* provide some real tools for the science teacher in real situations.

Across the major areas of his outline, Dr. Smith has found from his study of the current research that the trend is to endeavor to gain some information with respect to (1) principles as objectives for general education in junior high school science, biology, and chemistry and physics; (2) the development of attitudes and understanding of the scientific method in its application to specific situations throughout all of the categories; and (3) effective methods of producing desired results in one or more of the above purposes.

The teaching of basic principles, ability at problem solving, and scientific attitudes as objectives for pupils in grades seven through nine is indicative of continuing efforts to identify potential scientists and guide them into science courses beyond the generally required introductory ones. Increased effort is being directed toward the identification and recruitment of individuals who, at an early age, show talent in gaining and retaining basic principles, problem-solving ability, and scientific attitudes. Competition through science clubs, fairs, and science talent search programs has provided the stimulation for teachers and pupils alike in this direction.

In the area of biology, teachers have never come to agreement as to what ought to be taught; the most concerted notion has been that biology content should be governed by the natural environment of the school. However, a serious fallacy in this respect is that too often the teacher plays his own interest as the main theme and a large portion of the essential body of content is omitted or slighted. If a definite set of principles can be established, perhaps a number of approaches can be suggested in teaching them. Studies to establish such principles have been made, and probably an important adjunct now would be to work toward actually getting them agreed upon.

A definite need exists then in developing biology programs on the basis of what has been learned through research. Perhaps we need some research done upon the research that has been done in the past.

Busy teachers deserve simple, straightforward suggestions and recommendations, plus an incentive to try them out.

The research that has been done on the teaching of chemistry and physics bears out the somewhat hit-or-miss nature of that done in the other fields. Notwithstanding the fact that "laboratory" is a kind of central theme for most of the recent research in chemistry, there is still no uniform measure for comparison of achievement as related to the various methods employed; nor is there clarity with respect to what constitutes "laboratory." The term has come to be as general and varied in meanings as many other time-worn words and phrases. We do not know, when the word "laboratory" is mentioned, the kind of experience the speaker has in mind. It may be a pupil's investigation of some real problems which he is attempting to solve experimentally in a science laboratory; it may be a prescribed "recipe" from a manual, and may have no special meaning for him; he may be on a panel, or a trip to fulfill an assignment, devoid of any of the equipment or surroundings which the science teacher thinks of as laboratory. A biology class may be doing committee work, or simply drawing in a workbook, and it may be classed as "laboratory"; generally, I believe, the term "laboratory" is becoming broader in meaning, to embrace, in a good situation, any experiences a person undergoes to solve a problem from first hand investigation. However, researchers have not defined the term in such a broad way, nor have they agreed as to their own meaning of it; and thus a lack of clarity exists as to the implications of the experiences being described whenever the term "laboratory" is used.

There is, on the other hand, the connotation that the use of inductive-deductive procedures, regardless of the laboratory medium used, are favorable, provided the outcomes are the development of problem-solving abilities and proper scientific attitudes.

Gifted pupils who are successful, says Dean Smith, tend to exhibit cooperation and sympathetic understanding for their teachers. No doubt, they can also recognize when their teachers are practicing the scientific methods which they expound.

If teachers can and are willing to also recognize the difference between preachment and practice, and if they will extend sympathetic understanding, in turn, to their pupils and provide opportunity for each to learn as much as he is capable of learning, the gifted pupils will get along quite well. It is fairly certain that advanced courses in science will ultimately be taken by gifted pupils who have had adequate beginning science courses and that their training will develop effectively. The problem lies in getting the science-gifted pupils oriented.

SURVEY OF RECENT RESEARCH IN COLLEGE SCIENCE TEACHING

Beth Schultz

Western Michigan University, Kalamazoo, Michigan

Studies in the field of college science teaching include those published in *Science Education*, SCHOOL SCIENCE AND MATHEMATICS, *Journal of Experimental Education*, *The Basic College Quarterly*, *Metropolitan Detroit Science Review* and *American Journal of Physics*. A number of other periodicals publishing materials dealing with college teaching were examined but yielded nothing of worth. Additional sources included unpublished masters' and doctoral dissertations, in so far as these were available, and reports to the Committee on the Utilization of College Teaching Resources, supported by the Fund for the Advancement of Education, including their report, *Better Utilization of College Teaching Resources*.

These studies fall into four categories:

1. General education science course content
2. Methods of teaching
3. Science teacher training programs
4. Better utilization of teaching personnel and resources

In each of these categories there is a tendency to re-hash and re-evaluate ideas and methods which have been investigated and discussed extensively in the past: the block-and-gap courses contrasted to survey coverage, the question of integration of fragmented science fields, the value of teaching the history of science, the best way of teaching scientific methodology, the extent of actual preparation of science teachers as contrasted to desirable preparation, how to meet the problem of the teacher shortage, and the extent to which extended use of mechanical devices such as closed circuit television can supplement the teacher. There are, however, a few new ideas, some of which may advance the thinking along old lines, or possibly open up new ones. In general, more work of a concrete nature needs to be done to which science educators can point. At this time science education is being re-examined and criticized by the general public and their leaders, most of whom know little about it.

I. GENERAL EDUCATION SCIENCE COURSE CONTENT

College science faculties continue to seek answers to these important questions: What constitutes a good general education science course? What criteria should determine the organization, the content, and the method of a good science course? Today's college science faculties, now in the center of the educational stage, are continually developing new courses, trying them out, evaluating them.

Most general education science courses can be classed in one of these patterns: Survey type, integrated principles type, historical case study type, problem-area type, and problems type. There is a trend away from the survey course. The block-and-gap approach is much more widely used. Most teachers feel that any one field of science is too great to "cover" in a single course and that it is better to study fewer topics more deeply than to cover many superficially.

One author proposes a "multi-dimensional concept" of general education science. The proposal presents four ideas which should be of prime consideration as courses are being planned:

1. Depth is important.
2. Subject matter is a tool for getting at ideas.
3. Selection and organization of subject matter is determined by the goals.
4. Laboratory experiences are important in keeping the idea-oriented course from becoming overly deductive.

The multi-dimensional course should involve problem experiences. Some problems can be attacked through experiments, and others must be investigated by observation.

Other studies deal with specific courses. A physical science block-and-gap course presents students with two types of problems: unsolved problems, such as "How did the solar system originate?", and solved problems, such as "What is the best explanation for celestial motions?" Students investigate evidence for the commonly accepted answers. They reformulate and test the hypotheses which led to them. A history and philosophy of science course uses the case study approach. Space does not permit a detailed description needed to make the course convincing. However, students showed an increased awareness of the history of ideas and developed a historical perspective and appreciation of the scientific method. Students broadened the scope of their reading and were helped to relate the sciences to each other and to other disciplines.

Too much general education science continues to be directed toward the training of specialists and too little in the direction of the non-scientist. From this observation comes a proposal for the development of a socio-biological course. The course content should be determined by criteria of social worth. The author of this proposal selected four areas which are consistent with the objectives outlined in the report of the President's Commission on Higher Education:

1. Nervous activity and learning
2. Growth, reproduction, and heredity
3. Ecology and populations
4. Organic evolution.

Science requirements in the general education programs vary along a gradient from a liberal extreme to a conservative one. In the

extreme liberal plans, the science courses are electives. The extreme conservative plans require all students to take a specific course or combination of courses, regardless of the curriculum which they are pursuing. Midway along this gradient is a plan in one institution in which students are required to take 8 of a total of 16 semester hours which are offered. The offerings include biology, physical science, earth sciences and geography.

The development of integrated natural science courses is attracting increasing attention. It is necessary in such courses to bring together and unify materials from various fields. The emphases are on problems and processes common to all the sciences.

One of these courses has as its objectives:

1. An understanding of the nature of science
2. An understanding of the methods used by scientists
3. An active intellectual curiosity, open mind, passion for truth, respect for evidence, appreciation of need for free communication in science.
4. An awareness that boundaries of categorized sciences are largely artificial.

The methods used in presenting the course are: lecture, discussion, demonstration, and individual laboratory work. A faculty committee chose 29 problems suitable for inclusion in the course.

These descriptions of new courses and of how they were planned show that college faculties are paying closer attention to the needs and interests of the non-specialist, to the demands of society upon the individual, and to the nature of the learning process. The emphasis is shifting from the logical development of any one discipline to a psychological or interdisciplinary approach.

Most of the discussions of these courses center on selection and sequence of content. The teachers are planning together. One is left to wonder what part the students may have in the planning. Are students given opportunities to make choices, to devise and carry out plans of action? There are only a few studies which analyze methods of teaching.

II. Methods of Teaching

Methods of teaching are determined by the goals of the course, the nature of the content, the nature of the student, the physical facilities, and the nature of the teacher. A reasonable excuse for scarcity of research in science teaching methods is that any method must be based on assumptions concerning the learning process. Thus the basic research is actually investigation into the learning process. It is common knowledge that much more is known about learning than is applied in the teaching of any subject at any level.

Most of the studies on methods of teaching consist of comparing devices based on the various theories of learning. The researcher

must have a thorough awareness of uncontrollable variables, for it is easy to draw erroneous, and perhaps, dangerous conclusions.

A typical set of experiments was conducted with a natural science class to determine an effective way of teaching scientific methodology. Four methods were compared. At the end of the experiment, all four groups were tested for ability to interpret data and design experiments, as well as for knowledge of subject matter. The group which had used the laboratory inductive-deductive problem-solving approach scored highest in all of the tests. The discussion-recitation group ranked lowest on all tests.

One investigator became interested in a suggestion by Alfred Korzybski in his book *Science and Society* that a correlation exists between scientific preciseness of statement and social adjustment. For example, a person who has been taught to say and think "the leaf appears green" rather than "the leaf is green" would be better able to meet and solve problems in social adjustment. A test was devised and administered to a correctional institution group and to a public school group. The results support Korzybski's proposition.

In another study, the ACE tests of critical thinking, critical analysis and inventory of beliefs were administered as pre- and post-tests to large groups enrolled in a general education program—these included students from all curricula. In the critical analysis tests, students from science interest curricula gained more than those from non-science areas.

III. Science Teacher Training Programs

Science educators agree that prospective teachers should be taught to use facilities outside of the laboratory and the textbook. Direct experiences are more meaningful than symbolic ones. We find that our practice is not consistent with our beliefs. Laboratory and text books emphasize vicarious (symbolic) experience. Although much emphasis has been given to learning by direct experiences, these occupy less than one-tenth of the time spent in most classes.

A survey was made to find out what administrators want in the training of high school science teachers. It was found that administrators have two positive convictions regarding subject matter training. (1) They want teachers to be reasonably expert in at least one field of science. (2) They want the degree of specialization in both varied and particular fields to be such that the teacher can teach courses in more than one field of science. If a minimum standard of 60 semester hours of subject matter science is taken as a criterion, the majority of high school teachers of all science subjects are inadequately trained. Training in the supporting sciences (outside the

major) is generally inadequate. Lack of breadth of training is particularly evident among teachers of general science.

A state survey of science teachers revealed four basic patterns of teaching assignment. One of these combines a science with physical education. The other three are various combinations of sciences and mathematics. A state college then developed programs to prepare teachers for these assignments. The physical education major who wishes to teach science takes a biology minor plus twelve semester hours of supporting sciences. The other programs consist of a major in one field of science with minors designed to give support and breadth to the major. The total science course work is 50–60 semester hours.

It would seem that it is no longer advisable for teacher education schools to encourage science students to major or minor outside of science. The demands on the science teacher are so great that the time spent in major and minor should all be within the field of science. Is it possible, however, to force students to conform to such rigid patterns in the face of the present demand for science teachers?

IV. Utilization of Teaching Resources

During the academic year 1956–57, the Fund for the Advancement of Education supported about 35 studies and experiments in college teaching. The purpose of this project was to devise ways to meet the problem of college teacher shortage and increased enrollments. The science teacher shortage is especially acute; thus these studies which involved science teaching deserve our attention.

In several colleges, scientists from local industries are becoming part-time teachers. Many industries are generous in gifts to colleges in form of scholarships and funds for equipment, but these do little alleviate teacher shortages. One college developed a plan whereby the local industry made some scientists available during day class hours, while paying them their full salaries. The college also paid these teachers for their teaching, which necessarily required overtime work. Scientist participation was, of course, voluntary. The college cooperates by providing graduate courses toward M.S. degrees for the industry's employees. This plan has been successful and is suggested as an important contribution which industry can make.

A large college which employs many part-time instructors compared and evaluated the part-time and full-time college professors. Few differences were found between the two groups as to teaching goals and grade distributions. Students rated the part-time teachers slightly higher. The study resulted in suggestions to involve the part-time teacher more in planning, remove inequities in rank and assignment of duties, make all auxiliary services available to them, and to

plan to recruit more part-time instructors. Incidentally, as a part of this study, an Instructor Rating Schedule was formulated. The schedule was developed by collecting statements from many sources concerning the characteristics of good college teachers. The number of statements was reduced, tested and further reduced, and the final schedule consists of 40 carefully selected statements from an original pool of nearly 400. The method by which this schedule was developed and the final product are worthy to note.

A small college studied its organization to locate sources of waste of teaching resources. The single most important source of waste was judged to be the number of courses offered, particularly at the upper class level. Reduction of number of courses suggests re-planning courses and course programs. It was suggested that the greatest single obstacle to reducing the number of courses offered lies in the present system of departmental rather than area concentration. The implication is that in some instances there is considerable overlapping of course content and duplication of courses offered. A leading school of engineering also worked on this problem. When similar courses were offered in three to five departments, staff members cooperatively offered a single course. Results showed that learning qualitatively improved because the experimental courses were more unified and comprehensive.

Several projects centered on development of mechanical devices for teaching. These include such mass media as television, films, slide films, and recorded lectures. A technical institute worked out ways of improving two-way circuit television instruction. In overcoming some of the technical difficulties, this project may pave the way for better acceptance by faculty and students as well as better instruction. In another project, an interesting device for laboratory instruction was developed. Slide films with tape recordings permit students to have instruction and demonstrations repeated and to review material outside of class hours. Still another outstanding project involved the production of filmed lectures. The goal was to produce demonstration lectures by outstanding scholars in a particular specialty. In this way the superior work of outstanding teachers can benefit thousands of students. It is expected that this project will be continued and it is hoped that the films will be available to other colleges.

IMPLICATIONS OF RECENT RESEARCH IN COLLEGE SCIENCE TEACHING

W. C. Van Deventer

Western Michigan University, Kalamazoo, Michigan

Any consideration of the implications of recent research in science teaching at the college level must necessarily take into account the fact that all education, and certainly, at least by implication, all science education, is currently under attack by powerful outside agencies and personalities which have available considerable financial support, and which receive extensive publicity. It is unfortunate but true that these critics have little knowledge of things which are going on and which have gone on in science education. Therefore, they have little background from which to constructively criticize. It is nevertheless necessary, however, for science educators to be more than ever alert to the challenges which their field affords, and be prepared to demonstrate objectively that the answers which they are making to these challenges in the form of curricular developments, methodology and techniques are really the best answers available. If they are not the best answers, in that they show themselves deficient at the point of objective analysis and experimentation, then better answers must be found and tested. Without this approach, science education is not science, and possibly deserves some of the criticism which is levied against it.

A careful survey of the articles published in the field of science education during the period covered by the present report reveals far too little of the kind of attack which is necessary on the kind of problems that need to be attacked. There is too much re-hashing of old problems. There is too little objective seeking of answers to basic problems. There is too much opinion, too little fact.

For example, we still do not have the data to answer the question of what is the best approach to the development of a course pattern for general education college science: the survey type, the integrated principles type, the historical case study type, the problem-area type or the problems type. We have examples of apparently successful courses of each type. We have opinion, reams of it, but that is all. We are no nearer to an objective answer than we were ten years ago. True, we can discern a trend toward blocking-and-gapping, but this has only taken place because partisans of all types of courses have been driven in this direction by the sheer increase in the volume of material to be dealt with, together with the progressive tightening of total curricular requirements at all institutions.

One study among those reviewed classifies college requirements in

general education science along a gradient ranging from a "liberal" end where all such courses are elective, to a "conservative" end at which the same general education science work is required of all students, regardless of whether later they plan to specialize in science or in some non-science field. Here again we have a problem in regard to which there are reams of opinion but no objective answers. Is it true, as some partisans claim, that all students, even those who will later specialize in a science field, will profit measurably from having gone through a general education science course? Or is it true, as most teachers of traditional science courses claim, that a science major will naturally acquire, as a result of his total program, a grasp of the unique understandings which those in the general education science field believe are inherent in the approach which they use? Do such unique understandings really exist in the first place? Many of those who are now criticising science education do not believe that they do. The writer is confident that there are such understandings. However, we have no objective facts to cite. And if we can prove that such understandings do have an objective existence, must a student take a general education science course to obtain them? Again we do not know.

All this subjectivity and lack of objective information on our part leaves us open to the very kind of criticism which is being leveled against us. We may not deserve all of it or any of it. We may be one hundred per cent right, as we believe we are. But without objective data it is difficult to convince even an unbiased outsider that this is so.

Another area in which science education is open to criticism and can say little at present to defend itself is in the matter of the application of available information from the field of psychology on how students learn. The reviewer has said that "It is common knowledge that much more is known about learning than is applied in the teaching of any subject at any level." At the present time, when the virtues of the emphasis which a former generation of educators placed on drill, memorization and the so-called fundamentals are being extolled by critics, it would be well if we could cite more objective data to show that present teaching methods are achieving better results. Many of us believe that they are, and in a few cases objective data can be cited, but such cases are far too few. So long as the matter is left to subjective opinion, then to a lay person or a person in a governmental position, the opinion most lately and loudly expressed may well be considered "right."

Possibly the most provocative study which was reported was that of the investigator who was able to secure objective data supporting Alfred Korzybski's suggestion that a correlation would be found to

exist between scientific preciseness of statement and social adjustment. This is the kind of thing that we need more of. If further study bears out the results given, then all of the thinking and effort which are now going into general education college science courses of various types, and indeed into science education at all levels, emphasing abilities to observe and describe accurately and objectively, to locate and define problems and proceed logically toward attempted solutions, together with attempts to define and understand scientific methodology, will pay off richly in the long run.

Finally, we need objective answers to problems involved in the use of modern tools of teaching, such as closed circuit television, which technology is forcing upon us whether we like them or not, Involved are the necessities created by the coming into our institutions of masses of students, and the considerations of the financing of higher education that these entail. It is not just the question of whether or not students watching and listening to a televised lecture-demonstration get less, as much, or more out of it in terms of factual retention than they would from a face-to-face lecture accompanied by laboratory experience. Data which are being brought forward in this connection possibly are inadequate to prove the real teaching worth of televised experience or the opposite, in that they do not measure the "fringe benefits" of teacher-student relationships, and the possible advantage gained by the "feel" of the material. Here also, of course, we need objective data and do not have them. A larger question is this: If we have to use these devices, and it may well be that we will have to, regardless of what we think of them, how best can we do it? To do so effectively may well mean a new orientation to teaching problems, not only the old teaching problems but new ones too. It may not be simply a matter of doing our old job better, as one advocate of educational television recently put it in a meeting attended by the writer, but rather of going back and starting over again in our thinking, in terms of doing an entirely new job. It is possible that only in this way will we be able to meet this challenge. Otherwise we may well end up with science education merely mechanized and mass-produced, lacking the very real virtues inherent in our present procedure, and with none of the possible new ones that may inhere in the use of the new medium. It is the writer's opinion, again, unfortunately, without objective facts to back it up, that we may have "missed the boat" in this way a half-generation ago with educational motion pictures.

In all of this we need objective investigation above everything else, not only of the old problems about which we have written so much and really proved so little in the twenty years just past, but also of the wholly new problems of a practical nature which we cur-

rently face. We need data not only to answer the criticisms leveled against science education, but also to do our own job better. If we do not answer these questions ourselves objectively, they may well be answered for us subjectively by outside agencies, and we will end up being told what to do.

GOOD NEWS AND NOT SO GOOD—ABOUT SECONDARY SCIENCE AND MATH

Good news as well as news not encouraging about science and math education in public high schools will soon be released by the U. S. Office of Education.

Kenneth Brown, Federal specialist for science and mathematics, tells us that the forthcoming pamphlet on offerings and enrollments on these two subjects will show some gains and plenty of gaps. Dr. Brown had surveyed a random sampling consisting of about 10% of the public high schools. Here are some of his findings, reflecting offerings and enrollments during the fall of 1956.

Science in the Public High School

1. Forty-three per cent of the high schools surveyed by the Office of Education did not offer physics.
2. Thirty-six per cent did not offer chemistry.
3. Some small schools offer physics and chemistry on alternate years; however, 18.2% of the schools offered neither physics nor chemistry.
4. Ten per cent did not offer biology.
5. Schools that offered neither physics nor chemistry were small ones; they enrolled about 5% of all 12th grade pupils.
6. The percentage of pupils in the last four years of high school enrolled in physics has steadily decreased from 19% in 1900 to 4.4% in 1956.
7. From 1948 to 1956 the enrollments in physics increased from 291,000 to 310,000 or 6.5%. During this same period the number of high school pupils who normally could take the course increased 23%.
8. In the USSR the science requirement for the last four years is seven hours a week for each year. In the United States many schools require only five hours a week for one year. Thus, the USSR science requirement is five to six times as great as that in the United States public schools.

Math in the Public High Schools

1. One fifth of the high schools did not offer plane geometry, normally a tenth grade subject.
2. One third did not offer intermediate algebra, normally an 11th grade subject.
3. Two thirds offered neither trigonometry nor solid geometry, 12th grade subjects.
4. Some of the schools that did not offer mathematics were small ones; however, those schools that offered neither trigonometry nor solid geometry enrolled 28% of the pupils in the 12th grade.
5. A few schools offered special courses in advanced mathematics; however, 100,000 high school seniors were in schools where no mathematics of any kind above the 10th grade was offered.
6. The percentage of pupils enrolled in mathematics varies greatly from one geographic region to another. For example, one geographic region enrolled five times the percentage as another region.

Series Resonance

(Seventh in a Series)

Harald C. Jensen

Lake Forest College, Lake Forest, Illinois

Many concepts of physics ordinarily difficult to demonstrate become easy to illustrate if one is able to find just the right combination of elements for the demonstration equipment. The apparatus pictured in figure one for showing series resonance is a case in point. Only three components are required. While these are easy to secure and are relatively inexpensive, the combination tunes quite sharply to the ordinary 60 cycle per second frequency of the power line.

The resistor R is simply a 120 volt 7 watt light bulb such as those used for Christmas tree lighting. The inductor L is a filter choke[1] designed for use in power supplies of electronic devices. It should have an inductance between 10 and 15 henries and a current capacity of about 30 milliamperes. The specifications for the variable capacitor C are more stringent. The Cornell-Dubilier dial decade capacitor[2] with a range of 0.01 to 1.1 microfarads in steps of 0.01 microfarads is, however, a very satisfactory choice.

The circuit connections are shown in figure two. As C is varied from maximum to minimum, the condition of resonance is indicated

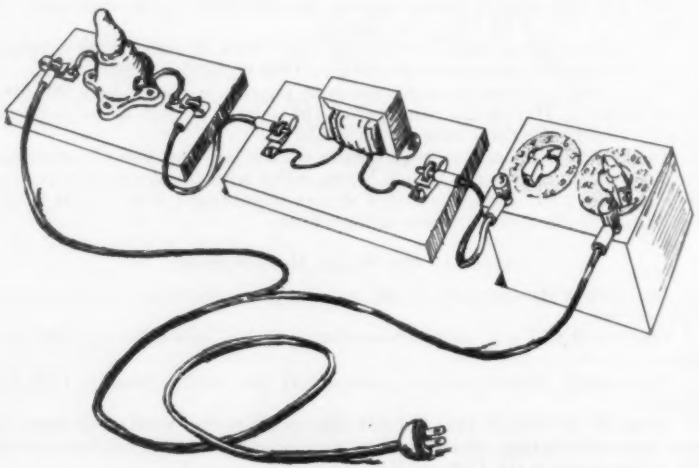

FIG. 1. Sketch of circuit useful for demonstrating series resonance. From left to right: resistor, inductor, and dial decade capacitor.

[1] Can be secured from suppliers of electronic or radio apparatus.

[2] #84F453, Allied Radio Corporation, 100 North Western Ave., Chicago 80, Illinois.

by the brightness of the light bulb. Note that the lamp bulb serves the dual purpose of resistor and ammeter.

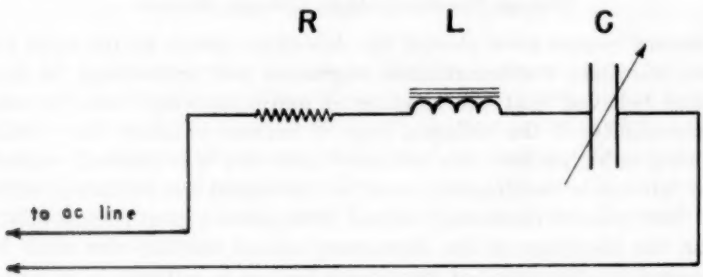

FIG. 2. Circuit diagram for series resonance circuit containing resistor R, inductor L, and dial decade capacitor C.

The combination also has quantitative possibilities. If the inductance of the choke is known and the capacitance at resonance is read, then one can make a calculation of the line frequency f from the relationship

$$f = 1/2\pi(1/\sqrt{LC}).$$

L and C can also be shorted out each in turn to show the effect of the other when in series with the lamp and the line. If an oscilloscope is available, the phase relations between the current in the circuit and the potential differences across R, L, and C can be shown quite simply. The phase differences between the respective potential differences can also be exhibited.

Since the concepts related to this apparatus are somewhat abstract, the apparatus is probably best suited for demonstration use.

LIVING HABITS CAN SPELL CANCER; PREVENTION NEW EMPHASIS

Living habits, such as the foods persons eat and their smoking, have much to do with whether they get cancer and what kind of cancer, Prof. V. R. Khanolkar, the new president of the International Union Against Cancer, told a press conference.

Prof. Khanolkar cited the example of the Chinese who have lived in Indonesia for many generations. They have a high stomach cancer incidence, whereas the native population has a low incidence. The two groups intermingle, experience common weather and other environmental factors but maintain their own cultural traditions, including diet.

Northern Indians, as another example, have a 14% total incidence of lip cancer while only 1% is found in Bombay residents. It is believed that the higher incidence for northern natives is caused by chewing tobacco held in the mouth. Cancer develops where the tobacco is held against the lip.

Preparation of Teachers of Arithmetic

David Rappaport

Chicago Teachers College, Chicago, Illinois

Recent events have alerted the American people to the need for more scientists, mathematicians, engineers, and technicians. At first it was believed that the training of mathematicians was the sole responsibility of the colleges, later it became evident that earlier training in high school was necessary, and now it is generally agreed that interest in mathematics must be developed and furthered while the child is in the elementary school. This places a great responsibility upon the shoulders of the elementary school teacher who must be prepared in other areas of learning as well as in arithmetic. In order to meet this responsibility the modern teacher of arithmetic is required to have a better understanding of the child, of the psychology of learning, and of the subject itself.

How well prepared to teach arithmetic is the elementary school teacher? What are the certification requirements? What arithmetic competencies should the elementary teacher have? What are the teachers' attitudes toward arithmetic? These will be discussed in the present paper.

Teachers' Preparation

Weaver has pointed out that, in the past, it has been assumed too often that the teacher did have an adequate understanding of the arithmetic she taught. He found that the teacher's arithmetic background was too often inadequate. He wrote:

> Before students can learn how to teach arithmetic meaningfully, they must have acquired the necessary breadth, depth and maturity of background in the subject-matter of arithmetic so that it may be a functional part of their preparation. Entirely too often this background of understanding and skill is *assumed*, thus becoming an unemphasized aspect of the over-all program of training. . . . All too frequently students are placed in teaching positions in elementary schools without having had any instruction *per se* since the days of their own elementary or junior high school study. Their point of view and degree of understanding is no broader nor deeper than that of the pupils they teach.[1]

Newsom found that too many teachers were only one step ahead of their good students.[2] Morton reported that 13.6% of the students in his education classes were below the eighth-grade norm in arithmetic and that some were even below the sixth-grade norm.[3]

[1] Weaver, J. Fred, "A Crucial Aspect of Meaningful Instruction," *The Mathematics Teacher*, 43: 116, March 1950.

[2] Newsom, C. V., "Mathematical Background Needed by Teachers of Arithmetic," *The Teaching of Arithmetic*, Fiftieth Yearbook, Part II, The National Society for the Study of Education. Chicago: University of Chicago Press, 1951. P. 232.

[3] Morton, R. L., *Teaching Arithmetic*, What Research Says to the Teacher, Pamphlet No. 2, Department of Classroom Teachers and American Educational Research Association of the National Education Association, 1953. P. 28.

Glennon conducted the most significant research study in this field. He devised a *Test of Basic Mathematical Understandings* composed of 80 items divided into five sections: Section 1, the decimal system of notation; Section 2, basic understandings of integers and processes; Section 3, basic understandings of fractions and processes; Section 4, basic understandings of decimals and processes; and Section 5, basic understandings of the rationale of computation. These items were limited to the arithmetic taught in the first seven grades of the elementary school. Glennon administered his test to 144 teachers college freshmen, 172 teachers college seniors, and to 160 teachers-in-service whose experience ranged from 1 to 34 years. He reported the following findings:

1a. Teachers college freshmen understand 44% of the basic understandings
1b. Teachers college seniors understand 43%
1c. Teachers-in-service understand 55%
2a. There is no significant difference in achievement of basic mathematical understandings between teachers college freshman and teachers college seniors. Persons preparing to teach did not grow in achievement during the four years of the program of teacher education.
2b. There is no significant difference between a teachers college senior who has had a course in the Psychology and Teaching of Arithmetic and the teachers college senior who has not had such a course.
2c. There is no significant difference in achievements between a teacher-in-service who has done graduate work in Psychology and Teaching of Arithmetic and one who has not done graduate work in that course. Graduate work in Psychology and Teaching of Arithmetic did not contribute to growth in basic mathematical understandings.
2d. Experience in teaching arithmetic is no guarantee that the teacher will grow in the understanding of the subject.[4]

It is of great interest that Glennon's findings remained unchallenged until Weaver made a similar study in 1956. Weaver administered Glennon's test to 92 students in the Fall of 1953, 92 students in the Fall of 1954, 63 students in the Spring of 1955, and 101 students in the Fall of 1955. The average for the 348 students was an understanding of 55.8%. Weaver retested one of the groups at the end of the semester's work in his methods course and found that the students gained an average of 14.2% in basic mathematical understandings. He concluded that a methods course is effective if taught properly.[5]

The evidence appears to show that prospective elementary teachers are not receiving adequate instruction in arithemetic itself. Teachers colleges have the very important task of teaching arithmetic to the prospective elementary school teachers as well as psychology and

[4] Glennon, Vincent J., "A Study in Needed Redirection in the Preparation of Teachers of Arithmetic," *The Mathematics Teacher*, 42: 389–396, Dec. 1949.

[5] Weaver, J. Fred, "A Crucial Problem in the Preparation of Elementary-School Teachers," *Elementary School Journal*, 56: 255–261, Feb. 1956.

methods courses. The teacher training program is influenced, of course, by the various certification requirements.

Certification Requirement

Several studies were made at various times to determine what are the certification requirements in different teacher training institutions. As was to be expected, there was, and there still is, a big range in training requirement in arithmetic in different states and institutions. The earlier studies are reported in order to reveal a trend or lack of trend in arithmetic requirements for teachers.

Judd and Morton sent a questionnaire to 142 institutions that were members of the American Association of Teachers Colleges (1932–3). They found that of 104 institutions, 84 required a course in arithmetic for teacher certification while 20 institutions had no such requirement. Six out of 96 institutions had no methods course in teaching arithmetic. Thirty institutions had prerequisites for methods courses in arithmetic while 71 had no prerequisites. Even the term arithmetic course had different meanings, for "69 indicate that it is classified as mathematics, 14 as education, 8 as mathematics and education, 3 as special methods, and 2 as socialized mathematics."[6]

Taylor made the first study of arithmetic requirement in teacher certification in 1928 and then repeated the study in 1935. The following figures taken from his study show the changes that took place between 1928 and 1935:

Table I*

		Per Cent Not Requiring Arithmetic	Per Cent Requiring 3 or More Sem-Hrs
Kdg-primary	1928	20.6	37.4
Kdg-primary	1935	29.7	30.6
Int. Grades	1928	10.2	62.6
Int. Grades	1935	28.3	34.8
Gram. Grades & Jr. H. S.	1928	9.9	59.4
Gram. Grades & Jr. H. S.	1935	51.4	28.1
Gen. Elem. Course	1928	45.8	28.9
Gen. Elem. Course	1935	14.8	48.1

* Taylor, E. H., "The Preparation of Teachers of Arithmetic in Teachers Colleges," *The Mathematics Teacher*, 30: 13, Jan. 1937.

[6] Judd, R. D. and R. L. Morton, "Current Practices in Teacher-Training Courses in Arithmetic," *The Teaching of Arithmetic*, Tenth Yearbook, National Council of Teachers of Mathematics. New York: Bureau of Publications, Teachers College, Columbia University, 1935. Pp. 157–172.

Table I shows that in 1935 fewer schools had a requirement for arithmetic in the teacher training program than in 1928, with the simple exception of their general elementary curriculum. Taylor also found that while the arithmetic that was offered as part of the teacher training program was sometimes classified as arithmetic subject matter, in 53% of the semester hours the arithmetic course was devoted to methods only.[7]

The states also have different certification requirements that range from less than one year of college work to four years of college training. Blyler reported that in 1945:

> Nineteen states require four years of training beyond high school; four states require three years of training of college grade; fourteen states require two years of training beyond high school; nine states require one year of training beyond high school; and two states require less than one year of training beyond high school.[8]

The latest study of the teacher training program for arithmetic teachers was reported by Grossnickle in 1951. He sent a questionnaire to 147 state teachers colleges, members of the American Association of Colleges for Teacher Education. He received 131 returns but was able to use only 129. He found that 65% of the colleges had the same program for all teachers, while 35% had a differentiated program, i.e., kindergarten-primary, intermediate, advanced, and general elementary. He also found that 76% of the colleges had no mathematics requirement for admission to the curriculum preparing teachers of arithmetic, while 24% required some form of mathematics.[9] This showed that in most teachers colleges many students had not had any mathematics for at least four years. This fact was of great significance in view of the fact that many of these colleges did not require any background mathematics in the curriculum for teachers of arithmetic. Grossnickle reported that the requirement of background mathematics for the different curricula was as follows: 33% for the kindergarten-primary grades, 40% for the intermediate grades, 47% for the advanced grades, and 65% for the general elementary curriculum.[10]

Grossnickle was also concerned with the question of whether the methods of teaching arithmetic was given as a special course or as part of a general methods course. He reported the following:

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[7] *Ibid.*, p. 13.

[8] Blyler, Dorothy, "Certification of Elementary School Teachers in the United States," *Elementary School Journal*, 45: 571, June 1945.

[9] Grossnickle, F. E., "The Training of Teachers of Arithmetic," *The Teaching of Arithmetic*, Fiftieth Yearbook, Part II, The National Society for the Study of Education. Chicago: University of Chicago Press, 1951. Pp. 207–8.

[10] *Ibid.*, p. 210.

TABLE II[11]

Curriculum	Average Number of Semester Hours	Number of Institutions Offering Instruction		
		Separate Course in Teaching Arithmetic		Instruction As Part of General Methods
		Required	Not Required	
Kdg-primary	1.4	27	18	8
Intermediate	1.9	14	6	7
Advanced	1.9	12	5	5
General Elementary	1.5	75	39	34

[11] *Ibid.*, p. 214.

Grossnickle drew the following conclusions based on the findings in Table II:

> This means that the average number of semester-hours in both background and professional courses is equivalent to about one course in arithmetic for one semester. A meager offering of this kind is inadequate to equip the teacher to do a satisfactory job in the teaching of arithmetic, especially since most of the colleges have no mathematical requirement for entrance from high school. As long as this situation exists in the training of teachers of arithmetic, the schools of our country are certain to be staffed with teachers who are not adequately trained to teach arithmetic except as a tool subject. When this philosophy is accepted, drill is the chief instrument in the teacher's professional kit.[12]

The National Education Association has reported great progress in the number of states that have required college graduation as a minimum for regular elementary-school teaching certificates. However, 13 states still require in 1957 less than a bachelor's degree. Of these states, one requires three years of college training, nine require only two years, two require one year, and one state requires only 12 semester-hours of college training.[13] While the requirement of a bachelor's degree is no guarantee that prospective teachers will be adequately trained in arithmetic, it seems reasonable to conclude that less than a bachelor's degree will almost certainly result in inadequate training in arithmetic.

NEEDED ARITHMETIC COMPETENCIES

There is general agreement by the writers on teacher training that the background course in arithmetic should deal with the concept and nature of number, the fundamental operations, fractions, deci-

[12] *Ibid.*, p. 217.

[13] National Education Association, "The Postwar Struggle to Provide Competent Teachers," *Research Bulletin*, Vol. XXXV, No. 3, October 1957, p. 123.

mals, and measurement. As is to be expected, there is some variation among specific programs. Newsom recommends the following program:

1. Evolution of arithmetical concepts and notations
2. Number—one-to-one correspondence
3. Positional notation
4. Properties of integers
5. Four basic arithmetical operations
6. The fractions
   a. Terminology
   b. Rational numbers
   c. Common fractions
   d. Decimal fractions
7. The arithmetic of measurement
   a. The process of measurement
   b. Systems of measurement
   c. Computation with approximate numbers
8. Applications
   a. Evaluation of formulas
   b. Ratio and proportion
   c. Business arithmetic
   d. Statistical concepts
   e. Probability[14]

Schaaf recommends a slightly different program

I. Number Concepts and Numeration
   A. Historical Development
   B. Theory of Numeration
II. Nature of Number
   A. Psychological Considerations
   B. Number systems of Algebra
   C. Logical Foundations of Arithmetic
III. Computation
   A. Historical Development
   B. Analysis of Theory of Computation
IV. Measurement
   A. Direct Measurement
   B. Indirect Measurement
   C. Elements of Statistics
V. Socio-economic Applications
   A. Arithmetic in the Home
   B. Arithmetic in the Market Place
   C. Arithmetic and Finance[15]

In order to develop the necessary competencies, Taylor recommended that every prospective teacher take at least eight semester hours of mathematics, including background mathematics and methods of teaching arithmetic.[16] Grossnickle recommended at least six semester hours in background mathematics and one course in the

[14] *Op. cit.*, p. 249.

[15] Schaaf, William L., "Arithmetic for Arithmetic Teachers," SCHOOL SCIENCE AND MATHEMATICS, 53: 540–542, Oct. 1953.

[16] Taylor, E. H., "Mathematics for a Four-year Course for Teachers in the Elementary School," SCHOOL SCIENCE AND MATHEMATICS, 38: 500, May 1938.

teaching of arithmetic.[17] Newsom recommended that the course covering his outline of needed background be required of all elementary school teachers.[18] In addition to the required courses in mathematics the above writers recommended that these courses be taught by people experienced in the field of arithmetic.

Attitudes of Prospective Teachers

The teacher's attitude toward his subject is one of the important factors in his success as a teacher. Dutton wrote that he always asks the students in his methods classes what their feelings are concerning arithmetic. He arrived at four significant conclusions:

1. A tremendous outpouring of unfavorable feelings toward arithmetic. The language used is expressive and emotional. Seventy-four percent of all responses were unfavorable.
2. There were seven responses to the reason why.
   a. Lack of understanding
   b. Teaching disassociated from life
   c. Pages of word problems
   d. Boring drill
   e. Poor teaching
   f. Lack of interest
   g. Fear of making mistakes
3. University students come to methods classes with antagonistic attitudes toward arithmetic.
4. The statements expressed . . . seem to be so highly charged emotionally that they will influence the learning of methods for teaching arithmetic for a large proportion of the class.[19]

The present writer's experiences were similar to Dutton's. Many of his students have informed him that they put off taking the required course in background mathematics for as long a time as possible because they had always disliked or feared mathematics. He feels that he has succeeded in removing most of the dislikes but not the fears.

Conclusions and Recommendations

Elementary school teachers have the very important responsibility of helping the elementary school child develop an understanding of, and an interest in, mathematics. In order to perform this task efficiently they must themselves have a better understanding of the basic concepts of mathematics than was characteristic of teachers in the past, or perhaps even the present. The teacher training institutions must shoulder the responsibility of preparing teachers to meet the educational needs of children in an atomic age. These institutions

[17] *Op. cit.*, p. 230.
[18] *Op. cit.*, p. 233.
[19] Dutton, Wilbur H., "Attitudes of Prospective Teachers Toward Arithmetic," *Elementary School Journal*, 52: 85-87, Oct. 1951.

should help prospective teachers overcome fear of, and present antagonism toward, mathematics. Certification requirements should be modified so that all prospective teachers are required to take adequate courses in background mathematics as well as methods of teaching arithmetic. The task is great but an understanding of the problems involved should lead to a program which will better prepare teachers to teach arithmetic in the elementary schools.

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OCEAN "RIVER" MAPPED BELOW EQUATORIAL CURRENT

A new swift-flowing "river" as strong as 1,000 Mississippis has been measured hidden in the depths of the South Pacific Ocean.

Speeding along three times as fast as the surface current, the south equatorial current, this new river flows eastward along the equator for at least 3,500 miles. Scientists have mapped its dimensions and found that it is some 250 miles wide and 1,000 feet deep.

The Method of Advancing Centroids Applied to the Graphic Determination of Mean Values and Moving Averages*

S. I. Askovitz

School of Medicine, University of Pennsylvania,
and
Albert Einstein Medical Center, Philadelphia, Pa.

A number of years ago, an analysis was undertaken of a series of human temperature data obtained by means of an automatic recording device.[1] There were more than twenty thousand individual temperature readings, each represented by a small x marked by the instrument on a roll of continuous graph paper. The investigators desired to know the average temperature for certain periods of time, as well as the general trend over various intervals. It was intended to study the effect of sleep, food, exercise, and other influences, and to analyze the differences between the results for male and female subjects. The statistical problems involved were certainly straightforward enough, but the great mass of graphic data spread over many yards of paper, and the limited time assigned for the project, made it imperative to search for abbreviated methods.

A brief review of the relevant literature in mathematics and statistics at that time[2] did not provide any solution. However, after a few attempts, rapid graphic techniques were finally developed which resulted in a great simplification of the work.[3] The desired results (mean values, moving averages, and the line of best fit according to the criterion of least squares) could be obtained directly on the graph

* Elaboration of part of the paper, "Rapid Graphical Methods in Statistics," presented at the Mathematics Colloquium of the University of Pennsylvania on December 1, 1955. The extension of the method of advancing centroids to moving averages first arose during an analysis of cancer statistics at the Tumor Registry, Hospital of the University of Pennsylvania, supported in part by the Penn Mutual Life Insurance Company Foundation for the Study of Neoplastic Disease and by an Institutional Research Grant from the American Cancer Society, Inc. The details were worked out at the Department of Therapeutic Research, School of Medicine, University of Pennsylvania, supported in part by Grant H-625 (C-6) from the National Heart Institute of the National Institutes of Health, United States Public Health Service, and at the Ophthalmology Research Laboratory of the Albert Einstein Medical Center, supported by a grant from the Weinstock Fund.

[1] The results appeared in the paper, "Diurnal Variations in Body Temperatures," by M. C. Mellette, B. K. Hutt, S. I. Askovitz, and S. M. Horvath, *Journal of Applied Physiology*, 3, pp. 665–675, May–June 1951. The purely statistical aspects were first presented in a paper by the writer, "Some Observations on Commonly Used Statistical Methods," read at the Annual Meeting of the Undergraduate Medical Association of the School of Medicine of the University of Pennsylvania on April 25, 1950. Because of its length, this paper was never published.

[2] G. W. Hervey, Director of Statistics of the American National Red Cross, later brought to the writer's attention a paper by R. McChesney, "The Graphical Construction of Moving Averages," *Journal of the American Statistical Association*, 23, pp. 164–172, 1928, which contained a graphic method for determining the mean of three ordinates. Earlier references were found and were included in a subsequent note, "Graphic Determination of Mean Values," *Science*, 122, p. 973, November 18, 1955.

[3] Askovitz, S. I., "Rapid Method for Determining Mean Values and Areas Graphically," *Science*, 121, pp. 212–213, February 11, 1955; "Mean Rates of Change and Least Squares—Interpretation and Rapid Graphic Methods," *Journal of Applied Physiology*, 8, pp. 347–352, November–December 1955; "Mean Rate of Change and a Graphic Method for Its Evaluation," *Science*, 123, pp. 507–509, March 23, 1956; and "A Short-cut Graphic Method for Fitting the Best Straight Line to a Series of Points According to the Criterion of Least Squares," *Journal of the American Statistical Association*, 52, pp. 13–17, March 1957.

paper, without any calculations and without the need for transcribing the recorded points into numerical values. The present article describes the general concept of "advancing centroids," and in particular its application to moving averages.

Centroids and Some of Their Properties

It may be recalled from elementary mechanics that the centroid is by definition the center of gravity or balance point of a composite mass.[4] For statistical applications, centroids of finite sets of points are of particular interest. In the simple case of just two points, the centroid is at the mid-point of the segment joining the two points, if the points are equally weighted. If they are not equally weighted, then the centroid lies upon the straight line joining the two points and divides the segment in a ratio equal to the ratio of the two weights, with the centroid always closer to the "heavier" point. In general, given a set of n points $P_i(x_i, y_i)$ and corresponding weights w_i (for $i=1, 2, 3, \cdots, n$), then the centroid $P^*(x^*, y^*)$ is defined as the point with coordinates $x^*=\sum w_i x_i/\sum w_i$, and $y^*=\sum w_i y_i/\sum w_i$. Thus, each coordinate of the centroid is equal to the (weighted) arithmetic mean of the corresponding coordinates of the constituent points.

Three important properties of centroids will be used in the following development. The first is the distributive-commutative property, or the fact that in determining the centroid of a set of points, one may proceed to include the points one by one, or by subgrouping, in any order. To find the centroid of a set of points A, B, C, and D, one might first locate the centroid of A and B, let us say at L, and then the centroid of L (to which must be assigned a mass equal to the sum of the masses of A and B) and C. Let M designate the centroid of the weighted points L and C. Then one could determine the centroid of weighted points M and D at the point N. Alternatively, one might, for example, find the center of gravity of B and D, and join this sub-centroid together with the point A. This new sub-centroid could finally be combined with C, and the result would coincide with the point N found previously. Or, one might locate the centroid of B and C, and the centroid of A and D, and then combine these two.

A second property of the center of gravity of a set of points is that if the points are symmetrically or uniformly arranged, the centroid will lie on the axis of symmetry or at their geometric center.

The third property of centroids which has been found useful is the following. If one or more points of a set are moved in a vertical direction only, then the centroid will also move in a vertical direction only. Thus, if the point A is replaced by a point A' lying on the

[4] The technical distinction between center of mass and center of gravity is of no concern here, and the designation "centroid" will be used for either term interchangeably.

vertical line through A, and B is replaced by another point B', etc. then the centroid of the primed points will lie on a vertical line through the centroid of the original points. This is most easily seen by noting that the formula for the x-coordinate of the centroid does not contain any of the y-values. Therefore, if the y-coordinates of the constituent points are varied but the x-coordinates are held constant, then the x-coordinate of the centroid will remain unchanged. This implies, of course, that the centroid could not have been displaced horizontally, although it may have moved in a vertical direction.

Mean Values

We are now prepared to consider arithmetic means on a coordinate chart. Let us start with five points A, B, C, D and E, (Fig. 1) assumed to have the same horizontal spacing unit s between them. To find the mean value of the heights of these five points is, to be sure, no great accomplishment. However, if this sort of determination needed to be performed many hundreds of times, or if the numerical values were not given in advance but had to be read individually from a scale on the chart, then the advantage of a direct graphic approach would be better appreciated.

In order to find the arithmetic mean of the y-values (and simultaneously of the x-values), it would suffice to locate the centroid P of the given points, equally weighted. Let us now replace the points A to E by the feet of the perpendiculars from them upon the x-axis, the five points A' to E'. The centroid of A' to E' lies at the mid-point C' of segment $A'E'$, according to the second property. Therefore, the center of gravity P of the five points A to E must lie somewhere directly above C', by the third property above. In the same way, the centroid of points A, B, C, and D must be situated above the mid-point N' of $A'D'$, and the centroid of A, B and C will be on the vertical line through B'.

We proceed as follows: Let us label the centroid of A and B, or the mid-point of the segment joining these two points, L. We now inquire as to the position of the centroid M of A, B and C. Replacing A and B by their centroid L, it is seen that the desired M must be located somewhere on the segment LC. However, it was seen in the preceding paragraph that the centroid of the points A, B and C must lie on a vertical line through B' (or through B). Therefore, the centroid of A, B and C is located at the point where LC is intersected by the vertical line through B.

Next, let us determine the centroid of A, B, C and D, by considering A, B and C replaced by their sub-centroid at M. The desired centroid for the four points must thus be located somewhere on the

segment joining M and D. But the centroid of A, B, C and D must also lie on a vertical line passing through the centroid N' of the projection points on to the x-axis. Therefore, N is to be found at the intersection point of MD with a vertical line $\frac{1}{2}s$ to the right of M.

It should now be obvious that each time a new point in the sequence is added, the segment joining the first to the last of the projection points on the x-axis becomes longer by one unit s, and therefore the centroid on the x-axis moves to the right by $\frac{1}{2}s$ at each step. Consequently, the new centroid of the original points must at each step lie on a vertical line one-half of a spacing unit to the right of the previous one. But each new centroid must also lie upon the line joining the previous centroid with the new point to be added. We have, then, merely to mark down the intersection point of the appropriate lines. Thus, we have a simple graphic method for finding the centroid of *any* number of points with equally spaced x-values, directly on the graph paper, without requiring any calculations at all.

Method: One starts with a ruler placed so as to join the first two points, and draws a line from the first point toward the second, stopping on the vertical line mid-way between the points. Then, without moving the pencil, the ruler is turned so as to join this intermediate point to the third point in the original series, and a line is drawn in this new direction, stopping on the vertical line $\frac{1}{2}s$ further to the right. This is continued, directing the ruler toward the next point of the original series and advancing to the right by $\frac{1}{2}s$ at each step, until all of the points to be averaged have been included. The height of the final centroid point represents the desired mean value.

The check procedure consists of starting at the right and working through the series of points toward the left. On the diagram, the correctness of the centroid W of G, H, I, J and K is verified by following along the dashed line from K.

It will soon become apparent that the actual drawing in of the segments AL, LM, etc., is not essential. After acquiring some degree of familiarity with the technique, one may mark down merely the *points* L, M, etc. And ultimately, even the intermediate points will not need to be written down.

Moving Averages

If a whole series of averages were required, instead of an isolated arithmetic mean, one could apply the above procedure repeatedly for each successive mean value. However, this was found to be unnecessary, and a simple observation led to a technique for obtaining all the moving averages by a single polygonal line. This will be illustrated for five-point moving averages.

In order to derive the mean value of the points B to F inclusive

from the average of A to E, we may reason as follows: The centroid P of points A to E must lie on a line joining the point A to the centroid Q of points B to E. This means that the points A, P and Q must all three lie on a straight line. Therefore, Q lies on AP extended. Also, the centroid of points B to E will be located directly above the centroid of the projection points B' to E' on the x-axis. The deletion of the point A decreases the length of the projection segment by s, and therefore the centroid must move to the right by exactly $\frac{1}{2}s$ (from P' to Q'). Thus Q can be located merely by drawing AP and extending the line until it intersects the next vertical line $\frac{1}{2}s$ to the right of P.

The addition of the point F into the average can now be performed by joining the centroid Q of B, C, D and E to the point F and marking the point R on this line, one-half of a spacing unit further to the right. Next, one joins the centroid R to the point B, and advances one-half unit to the right. This has the effect of eliminating the height of B from the mean. Then the point G is included, and so on. The procedure is repeated until the entire series has been completed. It is necessary only to apply a pencil and straight-edge on the graph paper, advancing from the first five-point centroid $\frac{1}{2}s$ to the right at each step, while the straight-edge is directed toward the point to be eliminated (four $\frac{1}{2}s$ spaces to the left) or to be added (five $\frac{1}{2}s$ spaces to the right).

It should be fairly obvious that this technique is applicable in general, whether there are five values to each average or any other number n. It may be found an added convenience to mark on the ruler the appropriate number of spaces to the left, $(n-1)\cdot\frac{1}{2}s$, and to the right, $n\cdot\frac{1}{2}s$, of a central mark, in order to find more quickly which point is to be eliminated or added at each step. This would be especially helpful for longer time-series.

To check the accuracy of one's work, the last of the moving average points should always be verified by the right-to-left procedure mentioned previously. Exact coincidence of the check-centroid with the last of the moving average points indicates that there has probably been no error.

If one should desire to check an intermediate value independently of the remaining averages, this can, of course, be done by the same procedure. It may sometimes be found desirable, however, to include the graphic steps in as small a space as possible in order to avoid confusion with other lines already present on the graph. This can be accomplished by working alternately toward the right and toward the left. Any centroid may be determined or verified by segments contained entirely within a space of $\frac{1}{2}s$ horizontally. An example is shown by the fine dashed line on the diagram, where the points included in arriving at the mean U are taken in the order G, H, F, I and E.

As remarked previously, the drawing in of the polygonal line will soon be found unnecessary, and after some experience, even the intermediate points need not be marked down. However, the intermediate points in the graphic procedure for n-point averages actually provide the entire series of moving averages for $n-1$ consecutive values. Thus, on the diagram, points N, Q and so on (the others being unlabeled) are the four-point moving averages.

Iterated moving averages may be obtained by reapplying the entire graphic procedure to the primary moving average points. One can in this manner readily work out "centered" moving averages. For example, to obtain six-year centered means for annually recorded data, the six-point centroids could first be determined graphically. Then the two-point moving averages for these centroids would provide the desired result. For two-point averages, of course, the graphic procedure reduces to merely taking mid-points of the segments joining adjacent points. It may sometimes be found advantageous to use pencils of different color, to distinguish the various series.

Geometric means may be obtained if the data are plotted on semi-logarithmic graph paper. Techniques similar to those described above have been developed for fitting the best straight line to a time-series according to the criterion of least squares, for handling irregularly distributed data, and for determining the mean and standard deviation of a frequency diagram.

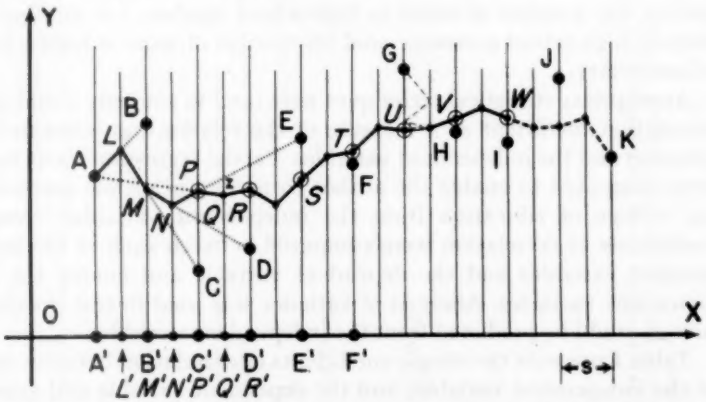

FIG. 1. Mean values and moving averages determined graphically. Original data are represented by larger dots A, B, C, $\cdots$, K. Solid polygonal line indicates the graphic procedure: $ALMNP$ to find mean value of the ordinates of A, B, C, D and E: $ALMNPQR \cdots W$ to determine the entire series of five-point (and four-point) moving averages. Encircled dots P, R, S, $\cdots$, W are the five-point averages. Intermediate centroids are shown by remaining dots, L, M, N, Q, $\cdots$. Dotted lines show position of ruler. Heavy dashed line K to W demonstrates recommended check procedure. Light dashed line G to U illustrates optional check on intermediate centroid U. Primed letters represent projections on to the X-axis.

High-School Mathematics Units and Success in a College of Education

Wilbur Waggoner

Central Michigan College, Mt. Pleasant, Michigan

This article is a report of a statistical study of the relationship between number and type of high-school mathematics units completed and academic success in the College of Education, University of Wyoming.[1] Interest in mathematics as a subject-matter field is at a high level. Being cognizant of the current emphasis on mathematics, the author felt that a study of the number and type of mathematics units completed in high school and success in a college of education would be of value. Information on this relationship is important to counselors, teachers, and administrators.

The sample of 139 students came from graduates of the four-year program in the College of Education during the period, 1951–1955. The University cumulative grade average was used as the criterion of college success. The eight independent variables used in the study were: (1) high-school grade average, (2) raw score on the Ohio State University Psychological Test, (3) standard score on the History and Social Studies section of the Iowa High School Content Examination, (4) whether a student majored or minored in mathematics or physical sciences, (5) number of units in high-school general mathematics, (6) number of units in high-school algebra, (7) number of units in high-school geometry, and (8) number of units in high-school trigonometry.

Appropriate statistical techniques were used to compute a multiple correlation coefficient as a measure of the relationship between the criterion and the independent variables. Partial regression coefficients were computed to enable the author to predict academic success in the college of education from the independent variables. Simple coefficients of correlation were computed between each of the independent variables and the dependent variable and among the independent variables. Analysis of variance was used to test if college success could be predicted from the independent variables.

Table I presents the simple coefficients of correlation between each of the independent variables and the dependent variable and among the independent variables. The negative correlations are due to the fact that the grading scale used at the University of Wyoming ranges from a superior grade of "1" to a failing grade of "5." High school grades of incoming freshmen are converted to the same scale by the Registrar's Office.

[1] Wilbur Waggoner, *The Relationship of High-School Mathematics to Success in College.* Unpublished Doctor's Project, Laramie: University of Wyoming, 1956, 175 pp.

TABLE I

SIMPLE CORRELATIONS AMONG ALL VARIABLES[1]

		1. High School Grade Average	2. Ohio Total	3. Iowa History and Social Studies	4. Major or Minor	5. Units of General Mathematics	6. Units of Algebra	7. Units of Geometry	8. Units of Trigonometry	9. University Grade Average
High School Grade Average	1.	1.0000	*.6474*[2]	*.2545*	*.0826*	.2854	*.2024*	*.0684*	*.0981*	.6458
Ohio Total	2.		1.0000	.4975	.1606	*.2606*	.2424	.2403	.1691	*.5698*
Iowa History and Social Studies	3.			1.0000	.2302	*.1702*	.1787	.3192	.1903	*.2524*
Major or Minor	4.				1.0000	*.0233*	.3963	.2283	.2692	*.1638*
Units of General Mathematics	5.					1.0000	*.3563*	*.3408*	*.0938*	.2346
Units of Algebra	6.						1.0000	.3855	.3993	*.2070*
Units of Geometry	7.							1.0000	.3888	*.1594*
Units of Trigonometry	8.								1.0000	*.0099*
University Grade Average	9.									1.0000

[1] $N = 139$, correlations of .2180 are significantly different from zero at the .01 level of confidence, correlations of .1668 are significantly different from zero at the .05 level of confidence, correlations of .1404 are significantly different from zero at the .10 level of confidence.

[2] *Underlined* correlations are negative.

The coefficient of correlation between the university cumulative grade average and these four independent variables were significantly different from zero at the .01 level of confidence: (1) high-school grade average, (2) scores on the Ohio State University Psychological Test, (3) scores on the History and Social Studies section of the Iowa High School Content Examination, and (4) number of units in high-school general mathematics. This means that if the hypothesis were true that there is no relationship between the criterion and the above independent variables, a correlation coefficient as large as was found could happen by chance less than one time in one hundred Due perhaps to the current practice in many secondary schools of putting the more mathematically able pupils in formal mathematics and the less able pupils in general mathematics, the relationship between high-school general mathematics and university cumulative grade average was in the opposite direction from the other mathematics variables.

The coefficient of correlation between the Ohio State University Psychological Test scores and the number of units in high-school algebra and high-school geometry tend to bear out the above supposition. The Ohio State University Psychological Test is a test of scholastic aptitude, and since the correlations between it and the number of units in algebra and geometry are significant in a positive direction; and the correlation of .2854 between it and units of general mathematics is significant in a negative direction, logically the statistician might suppose the more able students in mathematics are taking formal mathematics while the less able are taking general mathematics.

In contrast with the findings concerning the number of units of general mathematics, the analysis showed no appreciable relationship between the number of units in formal mathematics taken in high-school and the university cumulative grade average. The number of units in mathematics does not have an apparent effect on success in college.

To aid in answering the question whether the number and type of units in high-school mathematics has a significant relationship to a student's chance for success in a college of education, the independent variables were tested for regression, that is predictive power, with the criterion of university cumulative grade average. If there is significant regression between a variable and its criterion, this regression means that the variable can be used to predict the criterion score. Analysis showed that the independent variables could be used to predict grade average in a college of education. The hypothesis was tested that all the partial regression coefficients except the one for high-school grade average were equal to zero. This hypothesis could

not be rejected, and the conclusion was drawn that these variables could not be used to predict university cumulative grade average.

The partial regression coefficients give the weight of each variable in determining the criterion when the influence of the other variables is held constant. Hence, it can be ascertained just what role each of the several variables plays in determining the criterion score. From the analysis on the data, it was shown that high-school grade average had the greatest value among the independent variables in predicting university cumulative grade average when high-school grade average is placed first in a multiple regression equation with the other variables. From the regression analysis, it is apparent that when used with high-school grade average the number and types of high-school mathematics units are of little value for predicting university cumulative grade average.

TABLE II

COEFFICIENT OF MULTIPLE CORRELATION BETWEEN THE INDEPENDENT VARIABLES AND THE CRITERION

Independent Variable	Cumulative Coefficient of Correlation	Amount Added to the Coefficient of Correlation by Each Variable
1. High School Grade Average	.6458	.6458
2. Ohio Total	.6772	.0314
3. Iowa History and Social Studies	.6772	.0000
4. Major or Minor	.6816	.0044
5. Units of General Mathematics	.6819	.0003
6. Units of Algebra	.6819	.0000
7. Units of Geometry	.6835	.0016
8. Units of Trigonometry	.6842	.0007

Table II shows the coefficient of multiple correlation, and the amount added to this coefficient by each variable. The number of units in high-school mathematics did not add an appreciable amount to the coefficient of multiple correlation when they followed high-school grade average and the Ohio State University Psychological Test in the computation of this relationship. The four independent variables for high-school mathematics added .0026 to this measure of relationship. This table shows clearly what other investigators have found by different methods, namely, that the number of high-school mathematics units completed apparently has little relationship with success in college. Investigations of this kind need to be continued as the high-school curriculum evolves.

CONCLUSIONS

From the results of this study, it was apparent that the number of

units in high-school mathematics that a student has pursued has little effect upon his chance for success in the College of Education, University of Wyoming. It was not shown by any of the statistical tests used that the number and types of high-school mathematics units had a significant relationship with success in a college of education.

HIGHLIGHTS OF THE 1958 CONVENTION PROGRAM SECTION MEETINGS AND LUNCHEON PROGRAM

Clyde T. McCormick

Vice-President, CASMT, Illinois State Normal University, Normal, Illinois

This is the last of three articles describing the most important features of the program of the 58th annual convention of *Central Association of Science and Mathematics Teachers* which will be held at the Claypool Hotel in Indianapolis, November 27–29. We hope that these articles giving a preview will help the members and friends of the Association to make plans in advance to attend the convention and also to publicize it.

Previous articles dealt, in more detail, with various activities on Thursday and Friday:

1. The convention opens *Thursday evening* with a panel discussion centered around the general theme of the Convention "The Challenge of Science and Mathematics in a Free World." Dr. Thomas P. Carney, Vice-President of the Eli Lilly and Company, Indianapolis, will speak on "What is the Challenge of Science and Mathematics?" This will be followed by a discussion as to how CASMT is to meet the challenge on the *Elementary Secondary*, and *Advanced* Levels by Dr. Rose Lammel, Professor Paul Klinge, and Professor Ralph Huffer, respectively.
2. The first general session on *Friday morning* will be addressed by Professor E. H. C. Hildebrandt of Northwestern University. He will address the Association on "Our Debt to the Middle East—Can it be Repaid?" Following this address, Mr. Wayne H. Kincaid, Indianapolis, will demonstrate "Simple Devices for Teaching Atomic Structure."
3. An exceptional program made up of five parts is planned for *Friday afternoon*. Those attending the convention will have a choice of the following:
   (a) Tour to Pitman-Moore, a biological Company, Pre-registration required.
   (b) Tour to Allison Division of General Motors at one of the Speedway Plants
   (c) Tour to Instruction Center Indianapolis Public Schools, Pre-registration required.
   (d) A 3½ hour program in charge of Dr. Elbert P. Little representing the Physical Science Study Committee, Cambridge, Massachusetts.
   (e) A 3½ hour program in charge of Dr. Max Beberman representing the University of Illinois Committee on School Mathematics.
4. The *Friday evening* program should be a memorable one. Dr. H. J. Muller, Indiana University, a Nobel Prize Winner, will address the Association on "A Hundred Years without Darwinism are Enough."

This article will deal briefly with the activities on *Saturday*. The general session on Saturday morning, 9:00–9:40, will be addressed by Professor A. J. Lohwater, Department of Mathematics, University of Michigan, Ann Arbor, Michigan.

"A Comparison of the Soviet and American Programs in Science and Mathematics Education." A substantial part of the talk by Professor Lohwater will deal with the preparation of Soviet teachers of science and mathematics. During the summer, 1958, he went to the Soviet Union and to Poland and has had an opportunity to get a very recent look at their educational systems. This will be a most important and up-to-date address on a topic of keen interest.

Following the address by Professor Lohwater, six section meetings will be held from 9:45–11:45. Some of the sections represent combined sections in closely related areas. A number of well known speakers have consented to address the sections. A brief resume of the individual section programs follows.

The *Biology* and *Conservation* sections will present a combined program featuring talks by Mr. E. Garth Champagne, Chief, Division of Forest Utilization Research, Central States Forest Experiment Station, Forest Service, USDA, on "The Forest Yields New Products," and Dr. O. J. Eigsti, a Fulbright Scholar, Chicago Teachers College, Chicago, on "Effective Presentation by the Teacher." Here is a team of speakers which will present a top program.

The *Chemistry* section will have three speakers who will present an unusual program. Dr. C. W. Pettinga, Biological Research Division Eli Lilly and Company, Indianapolis, will speak on "New and Recent Developments in Biochemistry." Dr. Laurence E. Strong, Chairman, Chemistry Department, Earlham College will address the section on "Ideas and Chemicals." The third talk will be given by Mr. Marshall McCuen, Aircraft Engine Advanced Design and Development Group of the Allison Division of the General Motors Corporation.

The *Elementary Mathematics* and *Elementary Science* sections have combined their sections and the program will feature talks by Dr. Robert H. Koenker, Director of Graduate Studies and Professor of Education at Ball State Teachers College, Muncie, Indiana, on "Making Arithmetic Meaningful," and Sister Jean Marie, R.S.M., Assistant Professor of Education, St. Xavier College, Chicago, Illinois, on "Better Now?—or—Now?"—A Comparison of two Views of Elementary Science Education.

The *General Science* section will present Mrs. Cecil Gaines, Head of the Exact Science Department, Hutchins Junior High School, Detroit, Michigan, who will speak on "Demonstrations in General Science." In January, 1958, various school systems published reports on curriculum studies and curriculum revisions. These reports were given the journalistic title "Story." This "Story" will be considered by two very capable speakers. Dr. Elmer McDaid, Director of Exact Science, Detroit Public Schools, Detroit, Michigan, will speak on "The Follow Up on The Detroit Story." Dr. Newton Sprague, Consultant in Science and Mathematics, Indianapolis Public Schools, Indianapolis, will talk on "The Indianapolis Science Story—Now Two Years Old—The Year 1-A.S."

The *Mathematics* section will feature a program centered around the topic "Improvement of the High School Mathematics Curriculum." Dr. Charles Brumfield, Associate Professor of Mathematics, Ball State Teachers College, Muncie, Indiana, will discuss the experimentation that is now taking place throughout the country in serious attempts to improve the mathematics curriculum. Mr. Robert E. K. Rourke, Executive Director of the Commission on Mathematics, New York City, New York, will discuss the problems of curriculum construction in mathematics with special emphasis on the work of the Commission on Mathematics.

The *Physics* section will be of real interest to all physics teachers as well as to other science teachers. Dr. D. J. Tendam, Department of Physics, Purdue University, Lafayette, Indiana, will give an illustrated lecture on "Recent Developments with Particle Accelerators." Dr. Gilbert C. Finlay, Assistant Dean, College of Education, University of Illinois, Urbana, Illinois, will speak on "The Importance of the Physical Science Study Committee to Science Education."

Dr. Herman L. Shibler, Superintendent of Schools, Indianapolis, Indiana, will extend greetings and welcome at the noon luncheon.

The dynamic convention will terminate with two luncheon speakers from the U. S. Office of Education. Dr. Ellsworth S. Obourn, Specialist for Science, and

Dr. Kenneth E. Brown, Specialist for Mathematics will discuss "How the Federal Government, Congress and the President, are Meeting the Challenge and the up-to-date Measures taken by them or proposed by them for the Improvement and growth of Science and Mathematics Education in our Country."

(In 1951–1952, Dr. Obourn was on a UNESCO mission to Thailand where he served as advisor to the Minister of Education. In 1954 and 1955 he assumed a position as director of the UNESCO program for science education in Paris. Since the beginning of 1956 he has held the position of Specialist for Science in the United States, Office of Education.)

(In 1956, Dr. Brown was a delegate from the Department of State representing the United States Government at the International Conference on Public Education held in Geneva, Switzerland. He has written various publications for the Office of Education and mathematics education articles for The Mathematics Teacher.)

The Officers, the Board of Directors and the Section Chairman are proud to present one of the *finest programs in the history of CASMT*. Much time and energy, on the part of many, have gone into this convention in order that it will be a most hospitable and social affair. We trust that we have "left no stone unturned" in meeting the Challenge by presenting this program centered around *The Challenge of Science and Mathematics in a Free World.*

Come and bring some one to the 1958 convention of CASMT in Indianapolis, Claypool Hotel, November 27–29. More details of the program will be given in the Yearbook. If you have not received a copy, write for it.

Problem Department

Conducted by Margaret F. Willerding

San Diego State College, San Diego, Calif.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution or proposed problem sent the Editor should have the author's name introducing the problem or solution as *on the following pages.*

The editor of the Department desires to serve his readers by making it interesting and helpful to them. Address suggestions and problems to Margaret F. Willerding, San Diego State College, San Diego, Calif.

SOLUTIONS AND PROBLEMS

Note. Persons sending in solutions and submitting problems for solutions should observe the following instructions.

1. Solutions should be in typed form, double spaced.

2. Drawings in India ink should be on a separate page from the solution.

3. Give the solution to the problem which you propose if you have one and also the source and any known references to it.

4. In general when several solutions are correct, the one submitted in the best form will be used.

LATE SOLUTIONS

2513. *Robert B. Herrera, Los Angeles, Calif.*

2609. *J. Byers King, Denton, Md.*

2610. *Joseph M. Brandstetter, Chicago, Ill.*

2617. *No solution has been offered.*

2618. *Proposed by Richard H. Bates, Milford, New York.*

(a) Construct a line parallel to one side of triangle ABC which will intersect the other two sides and bisect the area of the triangle. Let such a line be called a *mediad*.

(b) Show that the three mediads of a triangle form three equal parallelograms and three equal trapezoids.

(c) Let a diagonal of each of the parallelograms of part (b) be called an *intermediad* and show that an intermediad is parallel to a side of the given triangle.

(d) If the triangle in the center of triangle ABC formed by the three mediads be called the *mediadic triangle*, show that the area of the mediadic triangle is

$$\frac{17-12\sqrt{2}}{2}$$

times the area of triangle ABC.

(e) Show that the centroid of the mediadic triangle is also the centroid of triangle ABC.

Solution by proposer.

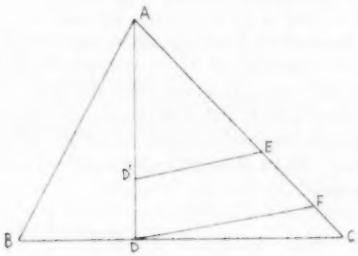

FIG. 1

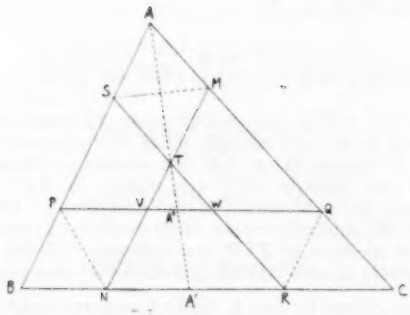

FIG. 2

(a) Without loss of generality let us construct the mediad parallel to side BC. Draw first the altitude AD of triangle ABC. Divide this altitude by the point D' so that $AD':DD'=1+\sqrt{2}:1$. Now through D' draw a line parallel to side BC meeting AB at P and AC at Q. The line PQ is the required mediad, for $AD':DD'=1+\sqrt{2}:1$ so $AD':AD=1+\sqrt{2}:2+\sqrt{2}$. Triangle APQ:triangle $ABC=(AD')^2:(AD)^2=(1+\sqrt{2})^2:(2+\sqrt{2})^2=1:2$.

The division of AD by the point D' into the ratio of $1+\sqrt{2}:1$ may be accomplished as follows: construct a square with a unit side whose diagonal will be $\sqrt{2}$. Then, as in figure 1, on the side AC take AE equal to the diagonal of the square plus a side of the square, and also the distance EF equal to a side of the square. The line DF is drawn and $D'E$ constructed parallel to DF determines the point D', since $AE:EF=1+\sqrt{2}:1$ so $AD':DD'=1+\sqrt{2}:1$.

(b) Let the three mediads be PQ, RS, and MN as in figure 2. Since PQ is parallel to BC and RS is parallel to AC, $WQCR$ is a parallelogram. $ASTM$ and $BNVP$ must likewise be parallelograms. Now triangles APQ and SBR and similar, (their sides are parallel) and equal (SR and PQ are mediads) hence they are congruent and $PQ=BR$. In like manner, from congruent triangles APQ and MNC, $PQ=NC$. Therefore $BN=RC$ and since $WQRC$ and $BNVP$ have equal altitudes they are equal in area, and similarly, they are each equal to $ASTM$.

The three equal (since MN, PQ, and RS are mediads) trapezoids, $ASRC$, $PQCB$, and $AMNB$ are each made up of a trapezoid and two equal parallelograms, hence the trapezoids $MTWQ$, $VWRN$, and $STVP$ are equal.

(c) If the proof of (b) it was shown that $PQ=BR$ and PQ is parallel to BR so $PQRB$ is a parallelogram, and QR is parallel to AB.

(d) $ASWQ+WQCR=PSW+ASWQ$ since PQ and RS are mediads, hence $WRCQ=PSW$. Since $WQCR$ is a parallelogram, $WQR=\frac{1}{2}WQCR=\frac{1}{2}PSW$. From part (c) QR is parallel to SP so triangle WQR is similar to triangle SPW, and $WQ:PW=1:\sqrt{2}$. From part (b) $WQ=PV$, hence $WQ:WQ+VW=1:\sqrt{2}$ from which $VW=WQ(\sqrt{2}-1)$. Now APQ is similar to ABC and its area is one-half of ABC so $(PQ)^2:(BC)^2=1:2$ or $PQ=BR=\frac{1}{2}\sqrt{2}\cdot BC$. But $WQ=RC=BC-BR=BC-\frac{1}{2}\sqrt{2}\cdot BC$ so $WQ=BC(1-\frac{1}{2}\sqrt{2})$. Therefore

$$VW=BC(1-\tfrac{1}{2}\sqrt{2})(\sqrt{2}-1)=BC\left(\frac{3\sqrt{2}-4}{2}\right)$$

The mediadic triangle TVW is similar to triangle ABC since its sides are parallel to the sides of ABC, hence its area, K' is to K, the area of ABC, as $(VW)^2$ is to $(BC)^2$, or

$$K':K=\left[BC\left(\frac{3\sqrt{2}-4}{2}\right)\right]^2:(BC)^2\,\frac{17-12\sqrt{2}}{2}$$

(e) If, from part (b), $ASTM$ is a parallelogram, AT must bisect SM and since SM is parallel to BC and triangle ASM is similar to triangle ABC, AT extended to A' bisects BC or AA' is a median of triangle ABC. But triangle ASM and triangle APQ are similar so AA'' also bisects PQ. $PV=WQ$ from part (b) so A'' is the midpoint of VW or TA'' is the median of TVW; similarly for the other medians of triangle TVW. Therefore the three medians of TVW are collinear with the medians of ABC and the centroids of each triangle are obviously concurrent.

Solutions were also offered by Jens L. Lund, Lafayette, Calif.; and C. W. Trigg, Los Angeles, Calif.

2619. *Proposed by M. Klamkin, Lawrence, Mass.*

Given an isosceles right triangle. Show how to determine the $\sqrt{2}$ correct to several decimal places by means of a pair of dividers.

Solution by C. W. Trigg, Los Angeles City College

Extend the hypotenuse AB of the isosceles triangle ABC indefinitely. Now if the value of $\sqrt{2}$ to 3 decimal places is desired, with dividers opened to distance AB, step off 1000 equal segments from A to D. Now close the dividers to distance AC, and count the number of equal segments which can be stepped off from A within AD. There will be 1414 with the remaining portion obviously less than one-half a segment. Hence, the desired $\sqrt{2}=1.414$. For each additional decimal place desired, increase the number of segments originally stepped off ten-fold.

Solutions were also offered by Bernard T. Pleimann, Gardena, Calif., and W. R. Smith, Passe a Grille Beach, Fla.; and the proposer.

2620. *Proposed by O. F. McCrary, Raleigh, N. C.*

A stack of pamphlets is in three piles. The first pile contains 1/6 of them, the second pile, several fifths of them, and the third pile, 6. What is the total number of pamphlets?

Solution by Brother Felix John, La Salle H.S., Philadelphia, Pa.

Let n equal the number of pamphlets.
Then,

$$n/6+kn/5+6=n.$$

$$n(25-6k)=180, \quad \text{or} \quad n=180/(25-6k).$$

This is a Diophantine equation: n must be integral.
If $k=0$, 1, 2, or 3, n is fractional.
If $k=4$, $n=180$, the number of pamphlets.
If $k\geq 5$, n is negative.
Proof: $180/6+720/5+6$ does equal 180.

Solutions were also offered by J. Byers King, Denton, Md.; H. R. Leifer, Verona, Pa.; Jens L. Lund, Lafayette, Calif.; James H. Means, Austin, Texas; Frank E. Milne, Halifax, N. S.; Brother Norbert, Chicago, Ill.; J. Phillips, Louisville, Ky.; Bernard T. Pleimann, Gardena, Calif.; Ben L. Swenson, Austin, Texas; T. C. Smith, Austin, Texas; W. R. Smith, Passe a Grille Beach, Fla.; C. W. Trigg, Los Angeles, Calif.; June West, Coral Gables, Fla.; Dale Woods, Pocatella, Idaho; and the proposer.

2622. *Proposed by Frank Peaslee, Cooperstown, N. J.*

Find x so that $3x^2+7x^3$ is a square.

Solution by C. W. Trigg, Los Angeles City College

$$N=3x^2+7x^3=x^2(3x+7)=x^2[3(x+2)+1]$$

Hence, we seek solutions for $y^2=3(x+2)+1$. Now y cannot be of the form $3p$, but if $y=3p+1$, then

$$9p^2+6p+1=3(x+2)+1$$

so

$$x=3p^2+2p-2, \qquad p=1, 2, 3, \cdots.$$

If $y=3p+2$, then

$$9p^2+12p+4=3(x+2)+1,$$

so

$$x=3p^2+4p-1, \qquad p=1, 2, 3, \cdots.$$

Thus we have two one-parameter solutions for x. Typical solutions for (x, N) are (3, 144), (14, 9604), (6, 900), (19, 23104).

Solutions were also offered by J. Byers King, Cooperstown, Pa.; F. John, Philadelphia, Pa.; H. R. Leifer, Verona, Pa.; James H. Means, Austin, Texas, Jens L. Lund, Lafayette, Calif.; Francis L. Miksa, Aurora, Ill.; Ray E. McLean, Sunnyvale, Calif.; Brother Norbert, Chicago, Ill.; J. P. Phillips, Louisville, Ky.; Bernard Pleimann, Gardena, Calif.; W. R. Smith, Passe a Grille Beach, Fla.; Ben L. Swenson, Austin, Texas; June West, Coral Gables, Fla.

2621. *Proposed by A. Elliott, San Diego, Calif.*

A man has six sons and proposes to divide his fortune among them. The amount has only 6 divisors (including unity) and each son is assigned one of these divisors. Each son will receive an amount equal to one plus the number of numbers having no common factors with and less than the divisor assigned. Further the sum of all the numbers less than that representing the fortune and having no factors common with it is one less than twice the amount to be divided. How much did each son receive?

Solution by the Proposer

Numbers having six divisors including unity must have either the form p^5 or p^2q, where p and q are prime. Next we can rule out the p^5 cases by reference to the last given condition.

Examining the p^2q case we find

$$2^2 \cdot 3 = 12$$

is one that satisfies all conditions of the problem. This provides the six sons with shares amounting to 1, 1, 2, 2, 2, and 4. The numbers referred to in the last condition (having no common factor in common with 12) are 11 and 7 and 5, their sum is 1 less than twice 12.

STUDENT HONOR ROLL

The Editor will be very happy to make special mention of classes, clubs, or individual students who offer solutions to problems submitted in this department. Teachers are urged to report to the Editor such solutions.

Editor's Note: For a time each student contributor will receive a copy of the magazine in which his name appears.

For this issue the Honor Roll appears below.

2619, 2620, 2622. *Lee H. Mitchell, 940 Sheridan Rd., Glencoe, Ill.*

2620 *Alan Zame, 941 Palermo Av., Coral Gables, Fla.*

2620. *James E. Ward, Caroline High School, Denton, Md.*

2620. *Walter Peters, Morris Kramer, Thomas Thomson, Arthur Cadorine, Fort Hamilton High School, Brooklyn, N.Y.*

2620. *Herb Pereyra, Serra High School, Gardena, Calif.*

2620. *Jeffrey Krauss, Bowen High School, Chicago, Ill.*

2618. *Herb Pereyra, Phil Strottner, Serra High School, Gardena, Calif.*

PROBLEMS FOR SOLUTION

2641. *Proposed by Brother Felix John, Philadelphia, Pa.*

Three roots of the equation

$$x^4+64x^3+819x^2+px+q=0$$

are in geometric progression with a common ratio 4. Find the 4 roots of the equation and also the values of p and q.

2642. *Proposed by B. C. Barrios, Cleveland, Ohio.*

Find an expression for the number of helically formed rods of diameter d that can be wrapped about a right circular cylinder of diameter D, such that each rod will touch the rod next to it. L is the lead of the helix, i.e., the distance parallel to the axis of the cylinder through which a point on the helix advances in one revolution.

2643. *Proposed by Alan Wayne, Baldwin, N.Y.*

As n increases without limit, what is the limit of

$$(\sqrt{1}+\sqrt{2}+\cdots+\sqrt{n})/(n\sqrt{n})?$$

2644. *Proposed by C. W. Trigg, Los Angeles, Calif.*

Show that for all integer values of x,

$$x^9-6x^7+9x^5-4x^3$$

is devisible by 8640

2645. *Proposed by John Nayler, Calgary, Alberta, Canada.*

A schoolgirl considers a bus ride "lucky" if the number of her bus ticket contains at least one 7. If the ticket numbers run in full sequence from 0001 to 9999, what is the chance than any one ride will be "lucky?"

2646. *Proposed by William W. Johnson, Cleveland, Ohio.*

Solve the equation

$$\sec\phi+3\csc\phi=5.7143.$$

Books and Teaching Aids Received

THE TEACHING OF GEOGRAPHY, by Zoe A. Thralls, *University of Pittsburgh*. Cloth. 339 pages. 14×21 cm. 1958. Appleton-Century-Crofts, Inc., 35 W. 32nd Street, New York 1, N.Y. Price $3.75.

THE WONDERWORLD OF SCIENCE, Book 7, Revised, by Morris Meister, Ralph E. Kierstead, Lois M. Shoemaker. Cloth. 352 pages. 14.5×21 cm. 1958. Charles Scribner's Sons, 597 Fifth Avenue, New York 17, N.Y. Price $3.12.

SPEECH CORRECTIONISTS: THE COMPETENCIES THEY NEED FOR THE WORK THEY DO, Prepared by Romaine P. Mackie, *Chief, Exceptional Children and Youth, Office of Education*, and Wendell Johnson, *Professor of Speech Pathology and Psychology, University of Iowa*. Paper. Pages ix+77. 15×23 cm. 1957. United States Government Printing Office, Washington 25, D.C. Price $.45.

ANALYSIS OF RESEARCH IN THE TEACHING OF SCIENCE—JULY 1955-JULY 1956, by Ellsworth S. Obourn, *Specialist for Science*. Paper. Pages v+55. 15×23 cm. 1958. U. S. Department of Health, Education, and Welfare. U.S. Government Printing Office, Washington 25, D.C. Price $.25.

CONCISE INTERNATIONAL DICTIONARY OF MECHANICS AND GEOLOGY—English-French-German-Spanish, By S. A. Cooper, *Fellow of the Institute of Linguists*. Cloth. Pages viii+400. 11×18 cm. 1958. Philosophical Library, Inc., 15 E. 40th Street, New York 16, N.Y. Price $6.00.

RECREATIONAL MATHEMATICS, by William L. Schaaf, *Brooklyn College, Brooklyn, N.Y.* Paper. 143 pages. 15×23 cm. 1958. National Council of Teachers of Mathematics, 1201 16th Street, N.W., Washington, D.C. Price $1.20.

COLLEGE ALGEBRA, 4th Edition, by Joseph B. Rosenback and Edwin A. Whitman, *Carnegie Institute of Technology*, Bruce E. Meserve, *New Jersey State Teachers College at Montclair*, and Philip M. Whitman, *The Johns Hopkins University*. Cloth. Pages xii+565+xlvi. 15.5×23 cm. Ginn and Company, Statler Building, Boston 17, Mass. Price $5.25.

FOUNDATIONS OF MODERN PHYSICAL SCIENCE, by Gerald Holton, *Associate Professor of Physics*, Harvard University, and Duane H. D. Roller, *Assistant Professor of the History of Science, University of Oklahoma*. Cloth. Pages xxiii +782. 15×22.5 cm. 1958. Addison-Wesley Publishing Co., Inc., Reading, Massachusetts. Price $8.50.

PLANE TRIGONOMETRY, 2nd Edition, by John J. Corless and Winifred V. Berglund, *Chicago Undergraduate Division, University of Illinois*. Cloth. Pages xii+397. 14.5×21 cm. 1958. Houghton Mifflin Co., 2 Park Street, Boston, Mass. Price $4.00.

A SOURCEBOOK FOR THE BIOLOGICAL SCIENCES, by Evelyn Morholt, Paul F Brandwein, and Alexander Joseph. Cloth. Pages xv+506. 16×23 cm. 1958 Harcourt, Brace and Co., 383 Madison Avenue, New York, N.Y.

INTRODUCTION TO DIFFERENCE EQUATIONS, by Samuel Goldberg, *Associate Professor of Mathematics, Oberlin College*. Cloth. Pages xii+260. 15×23 cm. 1958. John Wiley and Sons, Inc., 440 4th Ave., New York 16, N.Y. Price $6.75.

101 PUZZLES IN THOUGHT AND LOGIC, by C. R. Wylie, Jr. Paper. Unpaged 13.5×20 cm. 1958. Dover Publications, Inc., 920 Broadway, New York 10, N.Y. Price $1.00.

IMPEDANCE MATCHING, by Alexander Schure. Paper. Pages vii+119. 14×21.5 cm. 1958. John F. Rider Publisher, Inc., 116 W. 14th Street, New York 11, N.Y. Price $2.90.

A TREATISE ON ANALYTIC GEOMETRY OF THREE DIMENSIONS, by George Salmon, Revised by Reginald A. P. Rogers. Cloth. Pages xxiv+470. 13×20.5 cm. Chelsea Publishing Co., 552 W. 181 Street, New York 33, N.Y.

BASIC GEOMETRY, by George David Birkhoff, *Professor of Mathematics, Harvard University*, and Ralph Beatley, *Associate Professor of Education, Harvard University*. Cloth. 294 pages. 13.5×20 cm. Chelsea Publishing Co., 552 W. 181 Street, New York 33, N.Y.

PRINCIPLES OF CHEMISTRY, by Donald C. Gregg, *Professor of Chemistry, The University of Vermont*. Cloth. Pages xx+600. 15×22.5 cm. 1958. Allyn and Bacon, Inc., Boston, Mass.

MATHEMATICS FOR THE LAYMAN, by T. H. Ward Hill. Cloth. 343 pages. 11×18.5 cm. 1958. Philosophical Library, Inc., 15 E. 40th Street, New York 16, N.Y. Price $4.75.

MATHEMATICAL TABLES AND FORMULAE, by F. J. Camm, Cloth. 144 pages. 11×18.5 cm. 1958. Philosophical Library, Inc., 15 E. 40th Street, New York 16, N.Y. Price $2.75.

AN INTRODUCTION TO CHEMISTRY, by Charles Compton, *Professor of Chemistry, Williams College*. Cloth. Pages xiv+607. 15×23 cm. 1958. D. Van Nostrand Co, 120 Alexander Street, Princeton, N.J. Price $6.85.

BEHIND THE SPUTNIKS, A Survey of Soviet Space Science, by F. J. Krieger. Cloth. Pages vi+380. 15×23 cm. 1958. Public Affairs Press, 419 New Jersey Ave., S.E., Washington 3, D.C. Price $6.00.

THE TREASURY OF GAMES AND PUZZLES, compiled by Carlton Wallace. Cloth

256 pages. 21×14.5 cm. 1958. Philosophical Library, Inc., 15 E. 40th Street, New York 16, N.Y. Price $6.00.

ANALYTIC GEOMETRY PROBLEMS, by C. O. Oakley. Paper. Pages xviii+253. 13.5×21 cm. 1958. Barnes and Noble, Inc., 105 5th Avenue, New York 3, N.Y. Price $1.95.

THE STATUS OF SECONDARY SCIENCE EDUCATION IN THE STATE OF OHIO, by Charles L. Koelsche, *Professor of Science Education, The University of Toledo.* Paper. Pages iv+29. 1958, Research Foundation, University of Toledo, Toledo 6, Ohio.

ANATOMICAL ATLAS, Revised and Enlarged, by Maud Jepson. Paper. 29 pages. 22×28 cm. 1958. Rinehart and Co., Inc., 232 Madison Ave., New York 16, N.Y. Price $.95.

EXPERIMENTS IN PHYSICAL SCIENCE, by Allen D. Weaver, Ph.D., *Associate Professor of Physical Science, Northern Illinois University*, and James F. Glenn, M.S., *Chairman, Department of Science, State Teachers College, Salisbury, Maryland.* Paper. Pages xi+196. 22×28 cm. 1958. William C. Brown Co., Dubuque, Iowa. Price $3.00.

A NEW GEOMETRY FOR SECONDARY SCHOOLS, by Theodore Herberg, *Director, Department of Research and Curriculum, Pittsfield, Massachusetts Schools;* and Joseph B. Orleans, *Head of Mathematics Department, George Washington High School, New York City.* Cloth. Pages x+422. 13.5×21 cm. 1958. D. C. Heath and Co., Boston 16, Mass. Price $3.00.

RECURRENCE RELATIONS, by T. J. Fletcher. Paper. 22 pages. 13×20.5 cm. 1958. Mathematical Pie, Limited. 97 Chequer Road, Doncaster, England. Price $.20.

CHEMISTRY, MAN'S SERVANT, by Leonard J. Fliedner, *Principal, Stuyvesant High School, New York*, and Louis Teichman, *Chairman, Chemistry and Physics Department, George Washington High School, New York.* Cloth. Pages x+625. 16×23.5 cm. 1958. Allyn and Bacon, Inc., 41 Mt. Vernon St., Boston 8, Mass. Price $4.96.

FUNCTIONS OF COMPLEX VARIABLES, by Philip Franklin. Cloth. Pages ix+246. 14×21 cm. 1958. Prentice Hall, Inc., Englewood Cliffs, N.J. Price $6.95.

ARITHME-STICK AND GUIDE FOR YOUR ARITHME-STICK. Teaching aid for arithmetic. Ginn and Co., Statler Building, Boston 17, Mass. Price $4.50.

EXPERIMENTAL GENERAL CHEMISTRY, 3rd Ed. by J. W. Neckers, T. W. Abbott, and K. A. Van Lente, *All of Southern Illinois University.* Paper. 322 pages. 20×27.5 cm. 1958. Thomas Y. Crowell Co., 432 4th Ave., New York 16, N.Y. Price $3.50.

BASIC GENERAL MATHEMATICS, by Margeret Joseph and Mildred Keiffer. Cloth. Pages iv+458. 15×23 cm. 1958. Prentice-Hall, Inc., Englewood Cliffs, N.Y. Price $3.52.

BIOLOGY AND HUMAN PROGRESS, 2nd Ed., by Louis Eisman and Charles Tanzer. Cloth. Pages xiv+544. 15×23 cm. 1958. Prentice-Hall, Inc., Englewood Cliffs, N.Y. Price $4.80.

THE PHYSICAL WORLD, by Richard Brinckerhoff, Burnett Cross, Fletcher Watson, and Paul F. Brandwein. Cloth. Pages xii+450. 19×23.5 cm. 1958. Harcourt, Brace and Co., 383 Madison Ave., New York 17, N.Y.

SELECTED SCIENCE BOOKS FOR SECONDARY SCHOOLS, Compiled by R. Vincent Cash, E. Harold Coburn, Lucille E. Kuhnly, and Philip A. Hall. Connecticut

Science Teachers Association. Paper. 116 pages. 15×23.5 cm. 1958. Available from: Vincent Cash, Teachers College of Connecticut, New Britain, Conn. Price $.25.

WORKBOOK AND LABORATORY MANUAL TO ACCOMPANY HIGH SCHOOL PHYSICS, Rev. Ed., by Oswald H. Blackwood, Wilmer B. Herron, and William C. Kelly. Paper. Pp. vi+312. 19.5×26 cm. 1958. Ginn and Co., Statler Building, Boston 17, Mass.

IMPROVING SCIENCE PROGRAMS IN ILLINOIS SCHOOLS, Edited by William O. Stanley, Harry S. Broudy, and R. Will Burnett. Paper. 87 pages. 15×23 cm. 1958. University of Illinois, Urbana, Ill. Price $.25.

ELEMENTS OF PHYSICS, Revised by Paul J. Boylan, *Roxbury Memorial High School, Boston.* Cloth. Pp. xvi+677. 16×23.5 cm. 1958. Allyn and Bacon, Inc. 41 Mt. Vernon St., Boston, Mass.

BASIC AERONAUTICAL SCIENCE AND PRINCIPLES OF FLIGHT, by Robert D. Blacker. Cloth. Pp. xi+242. 15×23.5 cm. 1958. American Technical Society, 848 E. 58th St., Chicago 37, Ill. Price. $5.95.

LANGUAGE, THOUGHT, AND THE HUMAN MIND, by Chester A. Lawson. Cloth. Pages vi+117. 14×20.5 cm. 1958. Michigan State University Press, East Lansing, Mich. Price $4.50.

TEACHING ARITHMETIC FOR UNDERSTANDING. by John L. Marks, *Associate Professor of Mathematics and Education, San Jose State College, San Jose, California;* C. Richard Purdy, *Dean, Division of Sciences and Occupations, San Jose State College, San Jose, California;* and Lucien B. Kinney, *Professor of Education, Stanford University, Palo Alto, California.* Cloth. Pages xiv+429. 15×23 cm. 1958. McGraw-Hill Book Co., Inc., 330 W. 42nd Street, New York 36, N.Y. Price $6.00.

ELECTROSTATICS, edited by Alexander Schure. Paper. Pages vii+64, 14×21.5 cm. 1958. John F. Rider, Publisher, Inc., 116 W. 14th St., New York 11, N.Y. Price $1.35.

BASICS OF DIGITAL COMPUTERS, by John S. Murphy. 3 volume set. Paper. Vol. 1—116 pages; Vol. 2—133 pages; Vol. 3—136 pages. All 15×23 cm. 1958. John F. Rider Publisher, Inc., 116 W. 14th St., New York 11, N.Y. Price $2.50 per volume; $6.95 per set.

TEACHING HIGH SCHOOL SCIENCE: A BOOK OF METHODS, by Paul F. Brandwein, Fletcher G. Watson, and Paul E. Blackwood. Cloth. Pages xxi+568. 16.5×23 cm. 1958. Harcourt, Brace and Co., 383 Madison Ave., New York, N.Y.

DIFFERENTIAL EQUATIONS, by Forest Ray Moulton. Paper. Pages xv+395. 13.5×20.5 cm. 1958 Dover Publications, Inc., 920 Broadway, New York 10, N.Y. Rice $2.00.

MATHEMATICAL TABLES OF ELEMENTARY AND SOME HIGHER MATHEMATICAL FUNCTIONS, 2nd Ed., by Herbert Bristol Dwight. Paper. 217 pages. 13.5×20.5 cm. 1958. Dover Publications, Inc., 920 Broadway, New York 10, N.Y. Price $1.75.

JUVENILE DELINQUENCY, edited by Joseph S. Roucek. Cloth. 370 pages. 15×23 cm. 1958. Philosophical Library, Inc., 15 E. 40th St., New York, N.Y. Price $10.00.

HISTORY OF MATHEMATICS, Vol. I and II, by D. E. Smith. Paper. Vol. I—pages xvi+596; Vol. II—pages xii+725. 14×20.5 cm. 1958. Dover Publications, Inc., 920 Broadway, New York 10, N.Y. Price $5.00.

EDUCATORS GUIDE TO FREE FILMS, Eighteenth Annual Edition, 1958. Compiled and Edited by Mary Foley Horkheimer and John W. Diffor; Educational Consultant, John Guy Fowlkes. Paper. Pages xii+616. 21×27.5 cm. 1958. Educators Progress Service, Randolph, Wisconsin. Price $7.00.

HOW LIFE BEGAN by Irving Adler. Cloth. 128 pages. 14×21 cm. 1957. The John Day Co., Inc., 62 W. 45th St., New York 36, N.Y. Price $2.95.

MORE MARVELS OF INDUSTRIAL SCIENCE, by Burr W. Leyson. Cloth. 190 pages. 13.5×20.5 cm. 1958. E. P. Dutton and Co., 300 4th Ave., New York 10, N.Y. Price $3.50.

EXPLORING THE UNKNOWN—RESEARCH AT THE UNIVERSITY OF WISCONSIN. Paper. 94 pages. 21.5×28 cm. 1958. University of Wisconsin News Service, Madison 6, Wis.

THE TEACHING OF SCIENCE IN SECONDARY SCHOOLS, Rev. Ed., compiled by a Joint Committee of the Incorporated Association of Assistant Masters and the Science Masters' Association. Cloth. Pages ix+274. 14×21.5 cm. 1958. John Murray Co., Publishers, London, England. Price 17S. 6D.

Books Reviews

A NEW GEOMETRY FOR SECONDARY SCHOOLS, by Theodore Herberg, *Director, Department of Research and Curriculum, Pittsfield, Massachusetts Schools;* and Joseph B. Orleans, *Head of Mathematics Department, George Washington High School, New York City.* Cloth. Pages x+422. 13.5×21 cm. 1958. D. C. Heath and Co., Boston 16, Mass. Price $3.20.

A New Geometry for Secondary Schools is the third edition of an earlier textbook. The authors have attempted, on the basis of their experience in teaching mathematics, to include new trends in the teaching of plane geometry.

Adequate material has been presented for a college preparatory course; however, provision is made for the use of this textbook in a minimum course in geometry through the use of stars to indicate the more difficult exercises and proofs. Many of the more difficult proofs, and those of no immediate application are placed at the end of the textbook so that the student has an opportunity to have experience with easier items before encountering difficult ones.

Formal proofs are limited in number and many formulas, corollaries, and theorems are treated by an inductive method. An attempt is made to make the subject interesting to the student through the use of applications of geometry to science, industry, aviation and everyday life.

Applications of arithmetic, algebra and numerical trigonometry are made use of where they may be integrated easily with geometry. This makes it possible for the student to utilize his previous mathematical experiences in his study of geometry, and also introduces him to topics he will study in mathematics courses beyond the tenth-grade level. Coordinate geometry is used frequently as a means of tying in ninth-grade level mathematics with topics usually introduced in mathematics courses at the eleventh-grade level.

It is the opinion of this reviewer that this is an adequate textbook for a course in plane geometry. It probably will be acceptable to teachers interested in a traditional course in plane geometry and will satisfy some interested in a more "modern" approach to the subject.

J. BRYCE LOCKWOOD
Highland Park Junior College
Highland Park, Michigan

ARITHME-STICK, AND GUIDE FOR YOUR ARITHME-STICK. Teaching aid for arithmetic. Ginn and Co., Statler Building, Boston 17, Mass. Price $4.50.

The "Arithme-Stick" is an interesting instructional aid designed for use in the teaching of elementary arithmetic. It may be used in teacher demonstrations, individual pupil experimentation, or pupil-teacher manipulation. It should be a valuable device for teaching fundamental mathematical concepts at any elementary grade level.

The device is made of plastic tongued-and-grooved "sticks" that may be used separately or joined together. Plastic snap-on beads are used as counters. There are five "sticks" in all, so that they may be used singly to teach elementary concepts; or combined for use as a computer, number board, or abacus.

The manual of instructions is included to assist the teacher in becoming familiar with the potentialities of the device as a teaching aid. A few of the topics treated are: addition, subtraction, multiplication, division, counting, per cent, ratio and proportion, fractions, decimals, bar graphs, games, and averages.

The elementary-school teacher should have little difficulty in utilizing this device to make her elementary mathematics lessons more helpful and interesting to her students.

J. BRYCE LOCKWOOD

CHEMISTRY, MAN'S SERVANT, by Leonard J. Fliedner, *Principal, Stuyvesant High School, N.Y.* and Louis Teichman, *Chairman, Chemistry and Physics Department, George Washington High School, N.Y.* Cloth Pages x+625. 16×23.5 cm. 1958. Allyn and Bacon, Inc., 50 Beacon Street, Boston 8, Mass. $4.96.

This text book is well written to meet the needs of high school students. The material is organized around 12 units. The units and subjects are as follows:

Unit	*Subject*
1	Chemistry in Our Time
2	Water
3	The Structure of Matter
4	The Salt of the Earth
5	Sulfur and Sulfur Compounds
6	Nitrogen and Nitrogen Compounds
7	Chemical Reactions
8	Chemistry of Carbon
9	Classification of Elements
10	Nuclear Energy
11	Metals—The Sinews of Civilization
12	From Test Tube to Market

The units are followed by a sixteen-item appendix and a glossary.

The paper, general format, print, and illustrations are of superior quality. There is an abundance of well selected illustrations. The reviewer agrees with the following statements found in the preface: "The pupil will be using a text book written in a simple narrative style"—"The teacher will find in *Chemistry, Man's Servant*, a range and inclusiveness of subject matter suitable for the most rigorous college preparatory course."

The authors are to be commended on their unit 12, "From Test Tube to Market" which is devoted to applications of chemistry in agriculture, medicine, plastics, rubber, sulfa drugs, building, paints, textiles and photography.

Attention should also be directed to the excellent teaching aids found at the end of each chapter; they include: a summary, list of important terms, list of questions, and "things to do." The questions are divided into two groups: first, "What have you learned" which emphasizes factual recall and, second, "using what you know" which tests the student's ability to apply the principles developed in the chapter.

The book is right up to the minute in describing important recent discoveries.

For example, Nobelium, element 102, created in 1957 is listed among the transuranium elements on page 356. The authors did let a mistake appear in that on page 39, in giving the photograph of Dr. Irving Langmuir they gave only the year of birth and left blank the year of death. This would seem to indicate that he was still living, but actually he died in the summer of 1957. Yet, the book did not come off the press until 1958. The reviewer finds another weakness in the text in that the "atomic structure" chapter is separated from the "periodic table" chapter by over 200 pages. Many teachers wish to coordinate the material of these two chapters and hence like to have them developed rather simultaneously.

This text book should be a valuable guide either for an exacting college preparatory course or for a course which aims mainly at imparting practical everyday chemistry facts.

GERALD OSBORN
Department of Chemistry
Western Michigan University
Kalamazoo, Michigan

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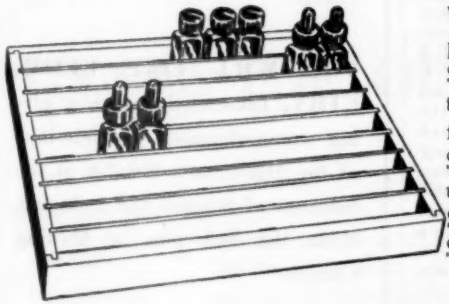

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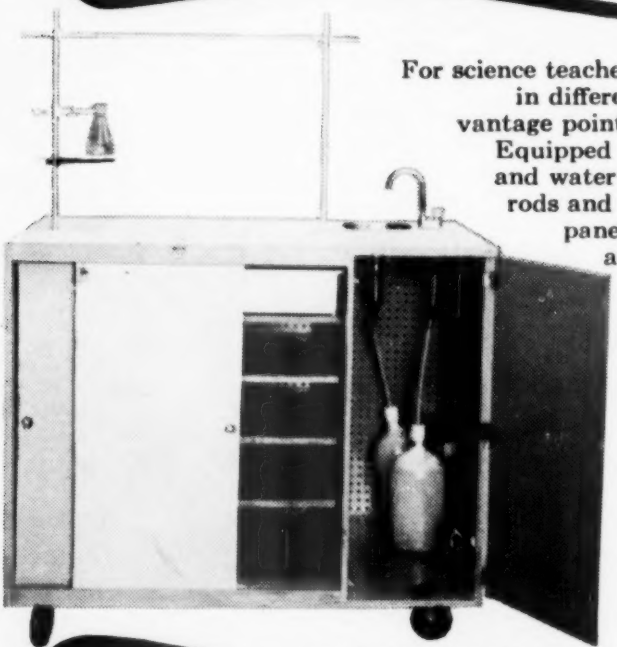

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